

TUTORIAL FOR READING TRMM DATA PRODUCTS

**TROPICAL RAINFALL MEASURING MISSION
SCIENCE DATA AND INFORMATION SYSTEM**

**Tutorial for Reading
Tropical Rainfall Measuring Mission (TRMM)
Data Products**

Release 1.1

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1. INTRODUCTION

The Tropical Rainfall Measuring Mission (TRMM) satellite was launched November 27, 1997 into a near circular orbit of approximately 350 km in altitude with an inclination of 35 degrees to the equator and a period of 91.5 minutes. The TRMM Science Data and Information System (TSDIS) processes TRMM data from the Precipitation Radar (PR), TRMM Microwave Imager (TMI), and Visible and Infrared Scanner (VIRS) instruments into data products oriented toward measuring rainfall in the tropics. This tutorial summarizes these data products and gives example programs to read them. More details on the data products and the TSDIS Toolkit, one method to read the products, are found in the Interface Control Specification Between the Tropical Rainfall Measuring Mission Science Data and Information System (TSDIS) and the TSDIS Science User (TSU). The six volumes of the Interface Control Specification (ICS) can be found on the World Wide Web (WWW) at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

2. TRMM DATA PRODUCTS

2.1 INTRODUCTION

Most TRMM Data Products are written using Hierarchical Data Format (HDF). This tutorial does not describe the few TRMM products not in HDF. The National Center for Supercomputing Applications (NCSA) developed HDF to be a standardized format readable on any machine. Documentation on HDF is available on the WWW at <http://hdf.ncsa.uiuc.edu/doc.html>. Four types of structures within an HDF file are of interest to readers of TRMM Data Products.

- (1) Metadata, or heading information, is contained in the HDF structure called a file attribute.
- (2) An array of data is contained in the HDF structure called a Scientific Data Set (SDS). All the elements of an SDS must have the same word type, for example 2 byte integer.
- (3) A table, or series of records, of data is contained in the HDF structure called a Vdata. A record is composed of several fields, each of which may be a different type.
- (4) The HDF structure called a Vgroup is a means of organizing data inside an HDF file, like a directory organizes files.

The figures that illustrate file structure contain either Vgroups or data objects (metadata objects, SDSs, or Vdatas). Figure 2.1-1 is an example of a product structure with annotations shown in italics. Vgroups are represented as the name of the Vgroup without a box. Data objects are represented as the name of the object inside a box. For metadata objects the estimated maximum total size appears on the right hand side of the box. If the object is a Vdata table, the size of one record appears on the right side of the box and the number of records appears next to the box. If the object is a SDS array, the size of one element appears on the right side of the box and the dimensions of the array appear next to the box.

The sizes for the metadata objects are estimated maxima since the values of many metadata are free text and may vary in length and not all metadata elements are used for all products. None of the sizes take HDF overhead into account. Previous (unpublished) experience gained in the TSDIS prototype study and the HDF internal feasibility study has shown HDF overhead to be less than 10% of the total file size for TSDIS products.

Missing satellite scans are filled with standard values denoting missing data. Missing satellite scans also have the “missing” byte in Scan Status set to 1. Values less than or equal to -99, -9999, -9999, -9999.9, -9999.9 denote missing or invalid data for 1-byte integer, 2-byte integer, 4-byte integer, 4-byte float, and 8-byte float, respectively. Any exceptions to the use of these standard values are explicitly noted in the description of the object. For the PR instrument, scans whose mode is other than observation mode are filled with missing values.

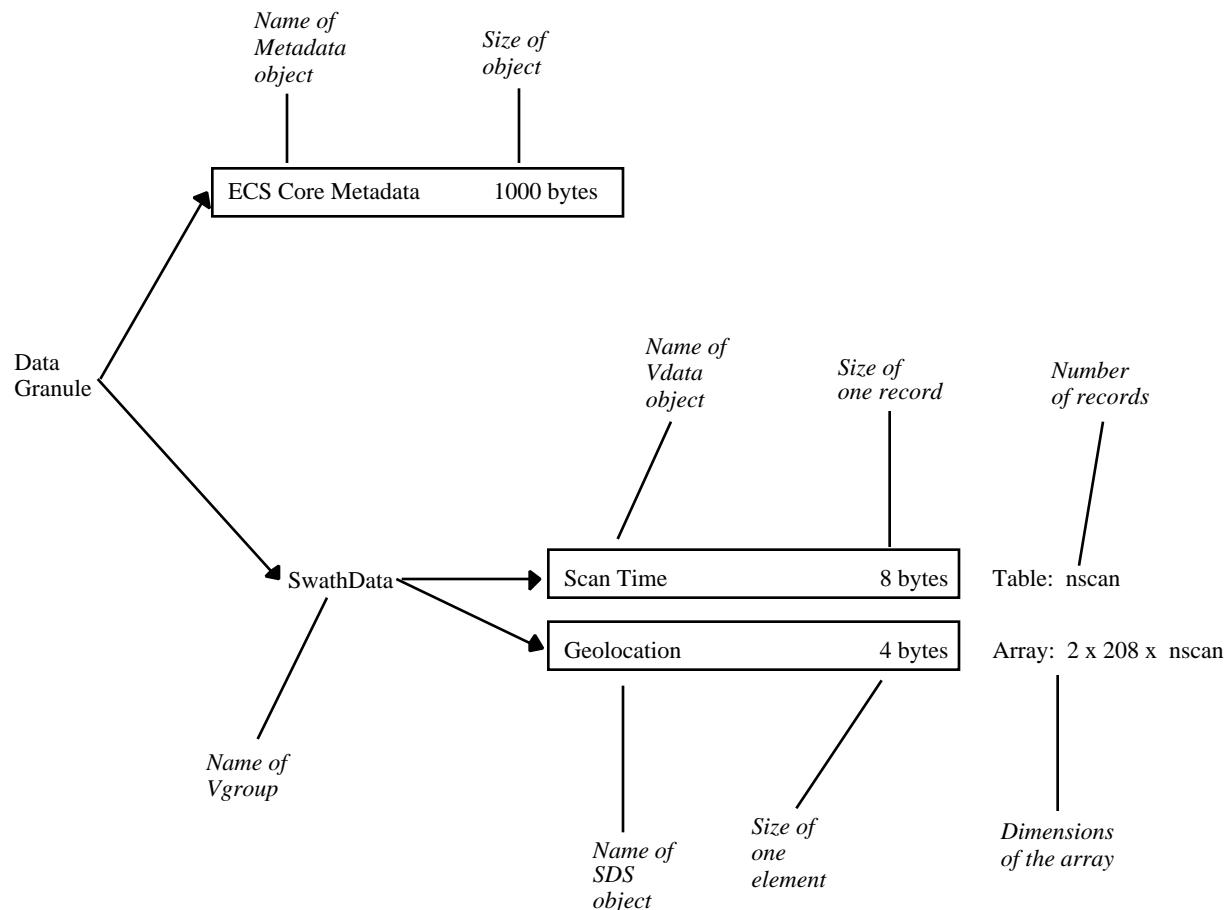


Figure 2.1-1
Example Product Structure

If an entire granule is missing, an empty granule may be created. If an entire orbit of Level 1B, 1C, 2A, or 2B satellite data is missing, scan data is omitted and the PS metadata named “Orbit Size” has the value zero. If an entire hour of Level 1B, 1C, 2A53, 2A54, or 2A55 Ground Validation (GV) data is missing, volume scan data is omitted and the PS metadata named “Number of VOS” has the value zero. An empty granule is not defined for pentad or monthly averaged data.

In the definition of array dimensions, e.g., npixel x nscan, the first dimension (npixel) has the most rapidly varying index and the last dimension (nscan) has the least rapidly varying index. To implement this format in FORTRAN, declare an array with dimensions as they appear in this document. To implement the format in C, declare an array with dimensions reversed from their appearance in this document.

The formats for TRMM products change. In the event of a disagreement between this Tutorial and the ICS (found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>), the ICS is correct.

Each of the following sections describes one product (one file) of the algorithm in the section heading. Structure figures are shown, but not descriptions of each variable.

2.2 1A-01

One file of 1A-01 contains raw VIRS science and housekeeping packets for one orbit. The output is in binary format and thus not the subject of this tutorial. The format is described in the ICS, Volume 3, available on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

2.3 1A-11

One file of 1A-11 contains raw TMI science and housekeeping packets for one orbit plus 50 extra scans before and 50 scans after the orbit. The output is in binary format and thus not the subject of this tutorial. The format is described in the ICS, Volume 3, available on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

2.4 1A-21

One file of 1A-21 contains raw PR science and housekeeping packets for one orbit. The output is in binary format and thus not the subject of this tutorial. The format is described in the ICS, Volume 3, available on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

2.5 1B-01

One file of 1B-01, VIRS Calibration, contains calibrated radiances for the five VIRS channels for one orbit. Bands 1 and 2 are reflected solar radiance. Bands 3, 4, and 5 are emitted thermal radiance.

Contact Dr. William Barnes at National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) Figure 2.5-1 shows the structure of 1B-01. The following sizing parameter is used:

- nscan = the number of scans within one granule (18026, on average)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

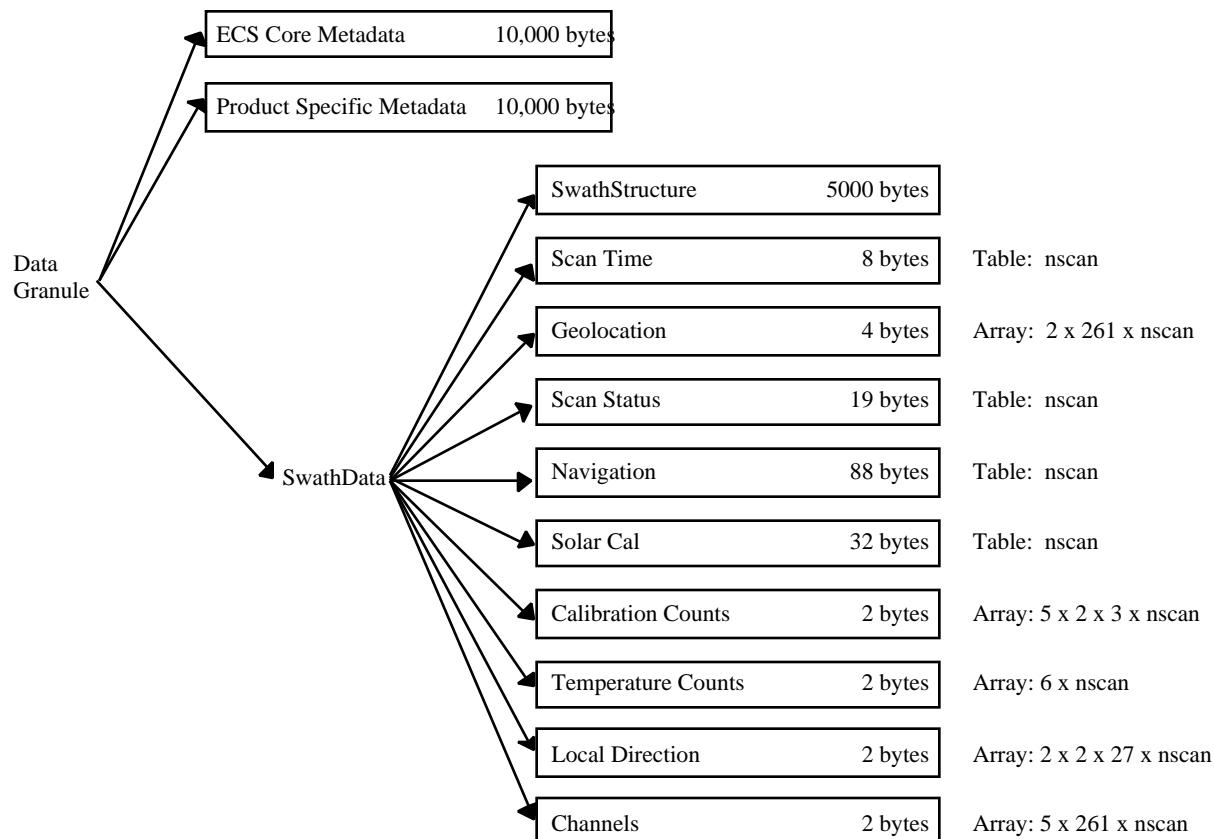


Figure 2.5-1
Data Format Structure for 1B01, VIRS Level-1B

2.6 1B-11

One file of 1B-11, TMI Brightness Temperatures, contains brightness temperatures for the 7 low resolution (10, 19, 21, and 37 GHz) and 2 high resolution (85 GHz) TMI channels for one orbit plus 50 extra scans before and 50 scans after the orbit.

Contact Dr. James Shiue at NASA/GSFC. Figure 2.6-1 shows the structure of 1B-11. The following sizing parameter is used:

- nscan = the number of scans within one granule (2991, on average)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

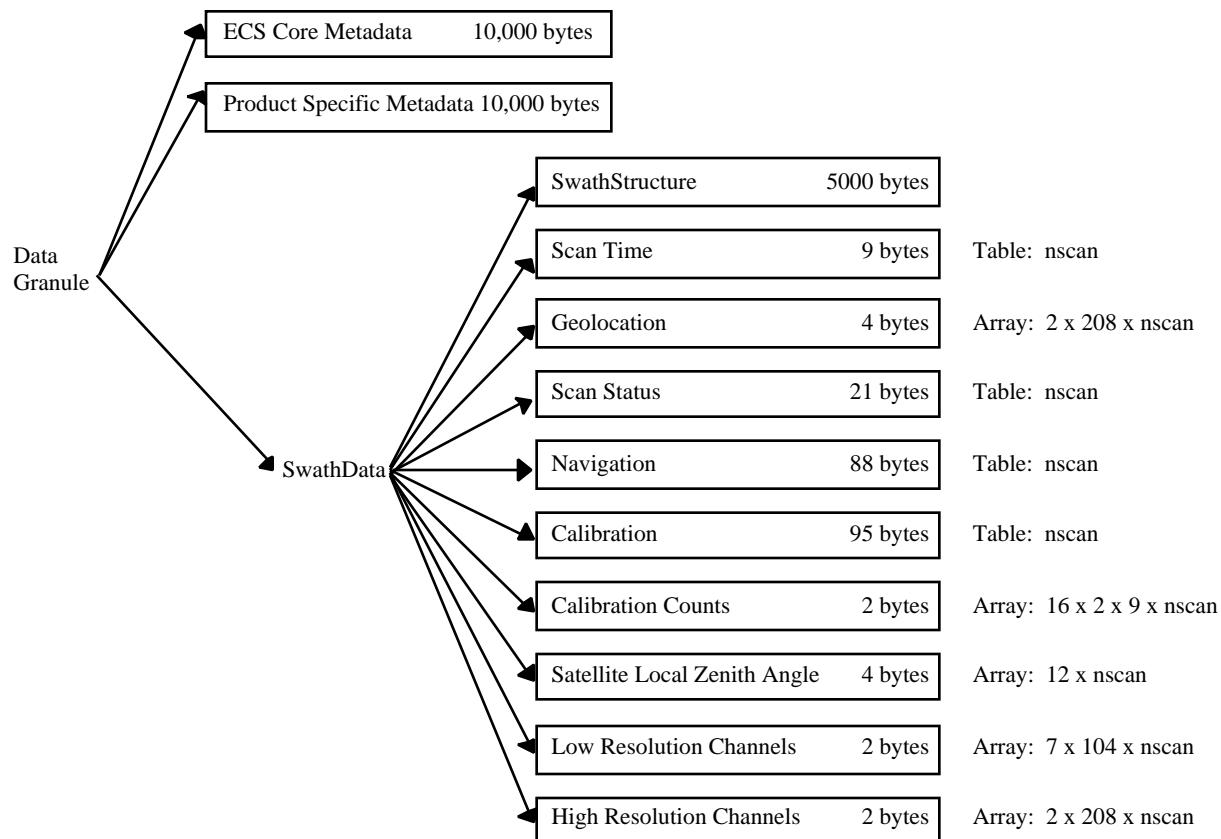


Figure 2.6-1
Data Format Structure for 1B11, TMI Level-1B

2.7 1B-21

One file of 1B-21, PR Power, contains calibrated PR powers for one orbit in 3 dimensional arrays whose dimensions are scan, ray (also called angle bin), and range bin. Power is written in three arrays: normal sample, surface oversample, and rain oversample. Values of -32734 and -32767 denote missing data. The vertical spacing is 250 m for the normal sample. If the surface oversample and rain oversample are combined with the normal sample, the result is 125 m vertical spacing in limited regions.

Contact Mr. Kazuhiro Hiroshima at National Space Development Agency (Japan)/Earth Observation Research Center (NASDA/EORC). Figure 2.7-1 shows the structure of 1B-21. The following sizing parameters are used:

- nscan = the number of scans within one granule (9150, on average)
- nray = the number of rays (49)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

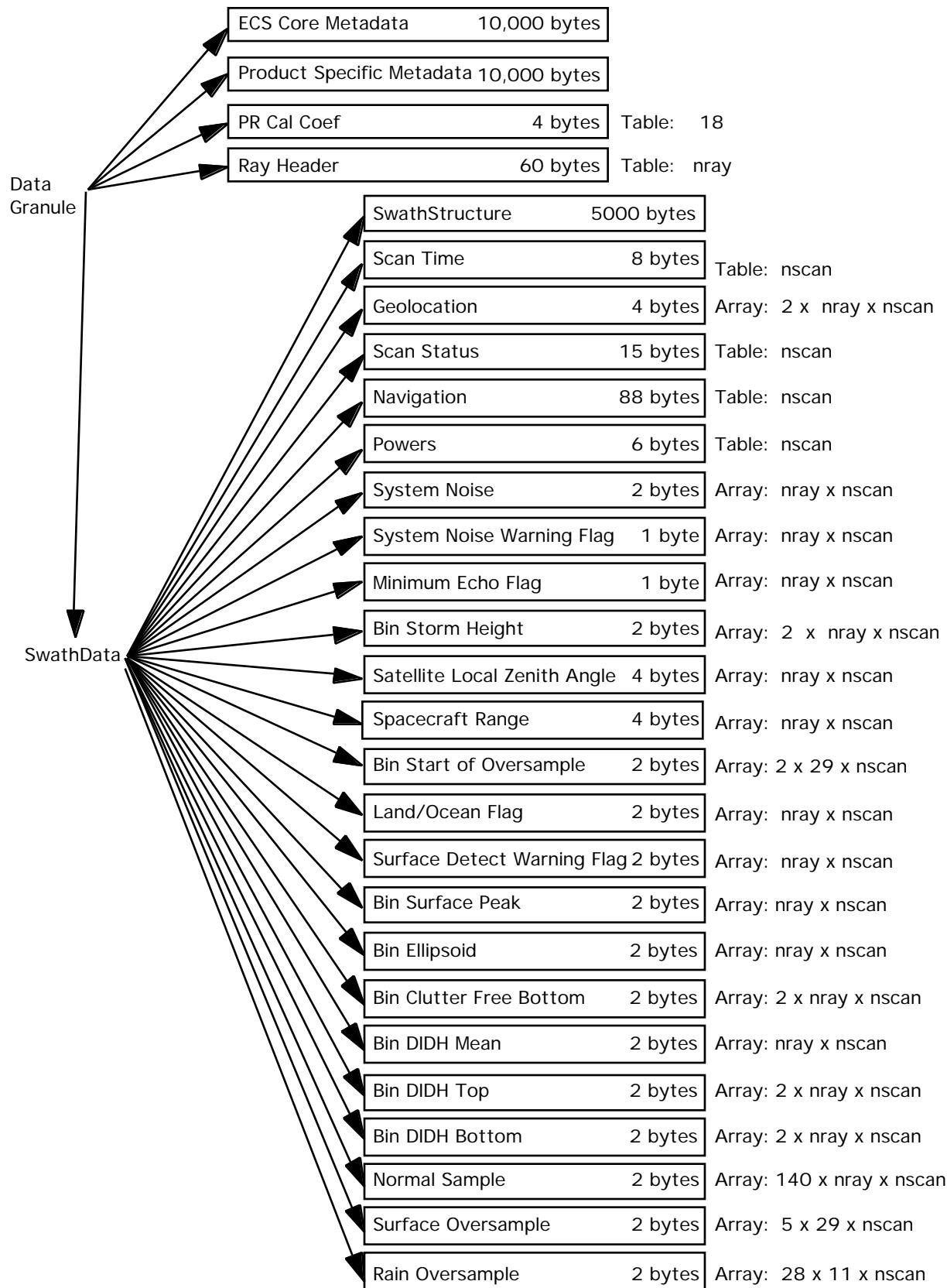


Figure 2.7-1 Data Format Structure for 1B21, PR Level-1B

2.8 1C-21

One file of 1C-21, PR Reflectivities, contains PR reflectivities in the same format as 1B-21. If a range bin is determined to have no rain, the reflectivity is set to -32700. Contact Mr. Kazuhiro Hiroshima at NASDA/EORC.

2.9 1B-51

One file of 1B-51, GV Calibration, contains raw reflectivity, possibly Doppler velocity and possibly other data in the original spatial and temporal resolution for one or more volume scans during one hour. The format is based on the DORADE format. The implementation of the format is variable depending on site and date of processing.

Contact Dr. Brad Ferrier at NASA/GSFC. Figure 2.9-1 shows the structure of 1B-51. The following sizing parameters are used and found at the location specified:

- nvos - Number of volume scans in granule. Provided in PS Metadata.
- nsensor - Number of sensors in a volume scan. Provided in Volume Descriptor.
- nparm - Number of parameters in a volume scan. Provided in Radar Descriptor.
- nsweep - Number of sweeps in a volume scan. Obtained from dimensions of Sweep Info
- nray - Number of rays in a sweep. Provided in Sweep Info.
- ncell - Number of cells in a ray. Obtained from Cell Range Vector.

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

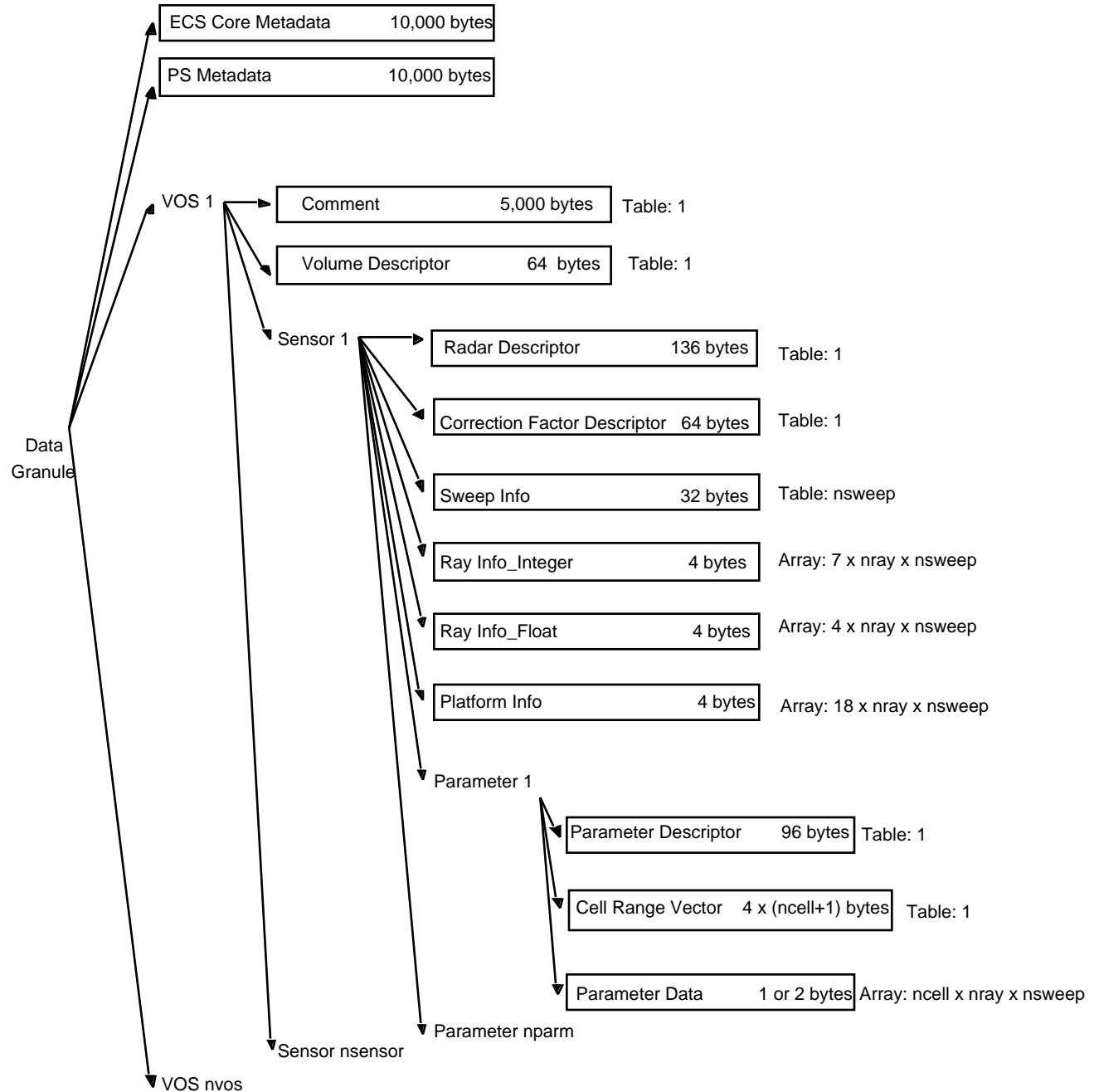


Figure 2.9-1
 Data Format Structure for 1B51, Ground Validation Level-1

2.10 1C-51

One file of 1C-51, Quality Control (QC) reflectivities, contains reflectivity and a quality mask and other data in the original spatial and temporal resolution for one or more volume scans during one hour in the same format as 1B-51. The format is based on the DORADE format. The implementation of the format is variable depending on site and date of processing.

Contact Dr. Brad Ferrier at NASA/GSFC.

2.11 2A-12

One file of 2A-12, TMI Profiling, contains vertical hydrometeor profiles for one orbit plus 50 extra scans before and 50 scans after the orbit. For each Instantaneous Field of View (IFOV), cloud liquid water, precipitation water, cloud ice, precipitation ice, and latent heating are provided at 14 levels. Surface rainfall and confidence are also given.

Contact Dr. Christian Kummerow at NASA/GSFC. Figure 2.11-1 shows the structure of 2A-12. The following sizing parameters are used:

- nscan = the number of scans within one granule (2991, on average)
- npixel = the number of high resolution pixels within one scan line (208)
- nlayer = the number of profiling layers within one pixel (14)
- ngeo = the number of geolocation data (2)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

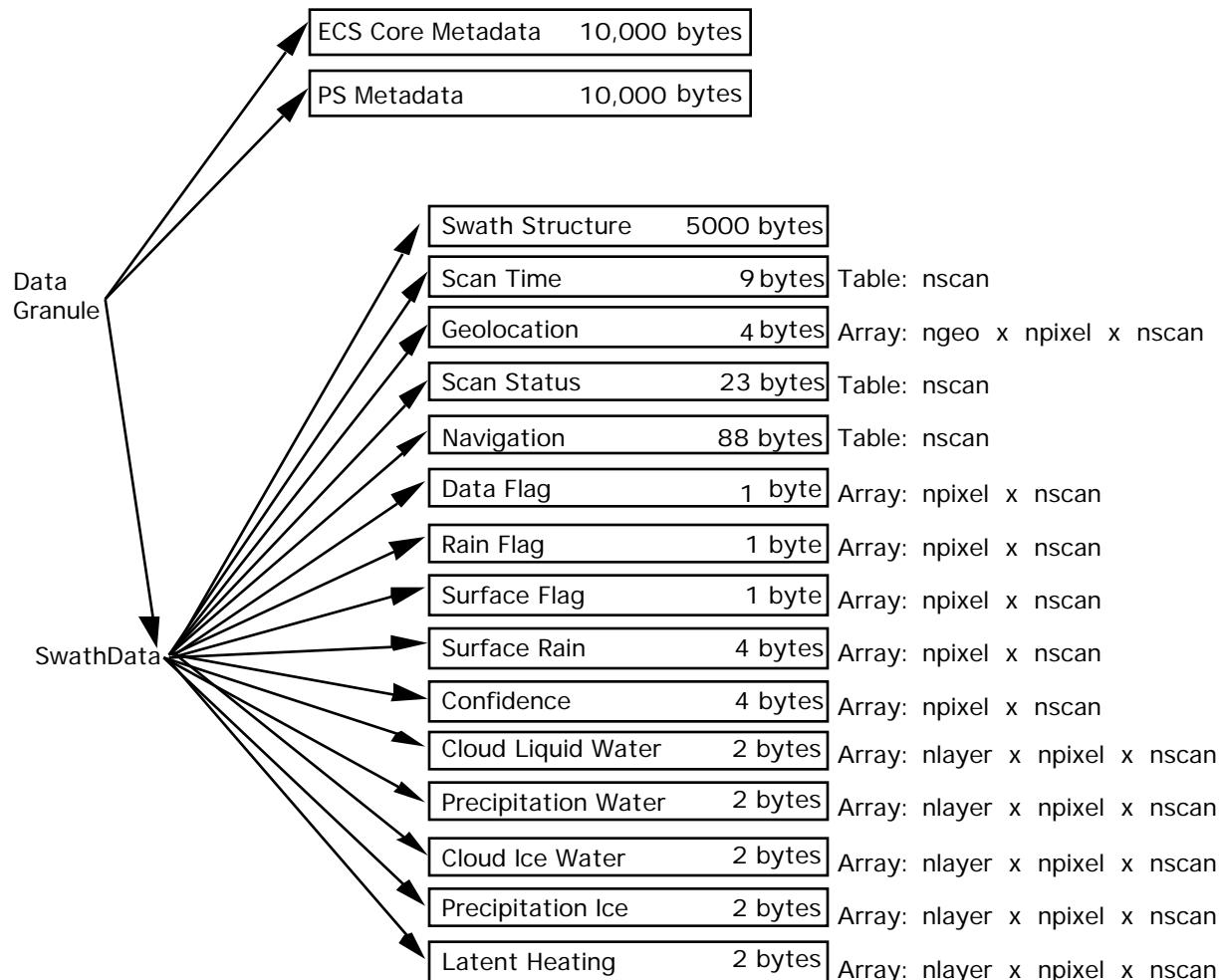


Figure 2.11-1
Data Format Structure for 2A-12, TMI Profiling

2.12 2A-21

One file of 2A-21, Surface Cross Section, contains normalized surface cross sections for one orbit. If rain is present, path attenuation and its reliability factor are also provided.

Contact Dr. Meneghini at NASA/GSFC. Figure 2.12-1 shows the structure of 2A-21. The following sizing parameters are used:

- nscan = the number of scans within one granule (9150, on average)
- nray = the number of rays (49)
- ngeo = the number of geolocation data (2)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

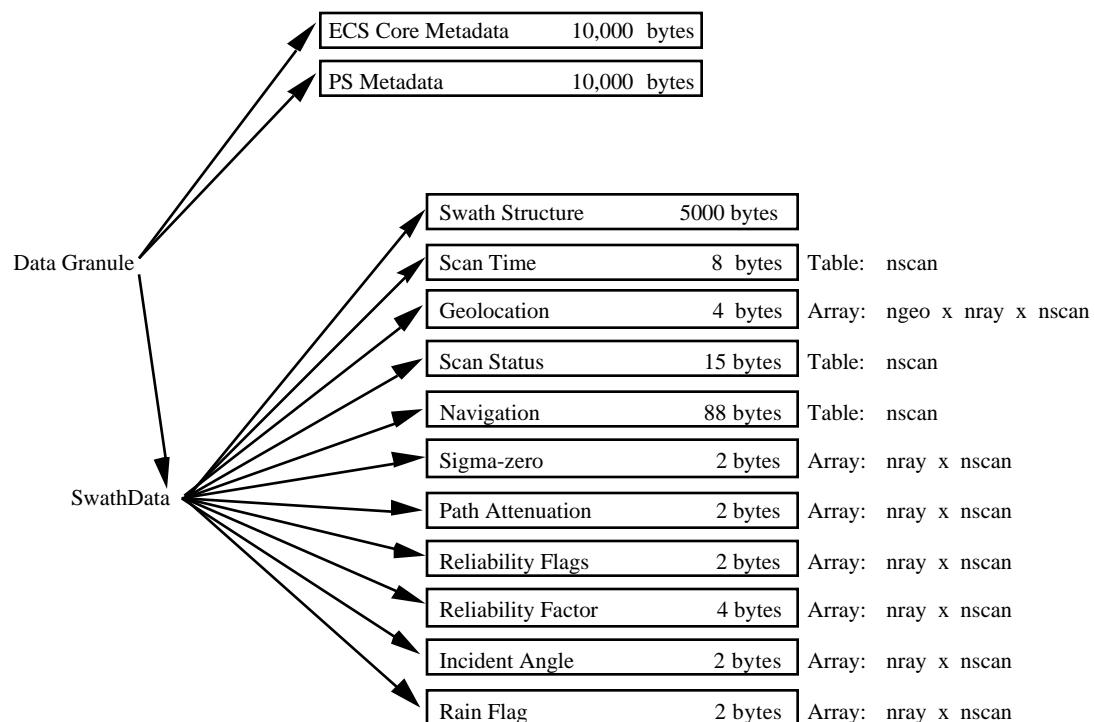


Figure 2.12-1
Data Format Structure for 2A-21, Surface Cross Section

2.13 2A-23

One file of 2A-23, PR Qualitative, contains Rain/No-rain flags for one orbit. If rain is present, bright band height, freezing level height, storm height and rain type are also provided.

Contact Dr. Jun Awaka at Hokkaido Tokai University/Dept. of Electronic and Information Engineering. Figure 2.13-1 shows the structure of 2A-23. The following sizing parameters are used:

- nscan = the number of scans within one granule (9150, on average)
- nray = the number of rays (49)
- ngeo = the number of geolocation data (2)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

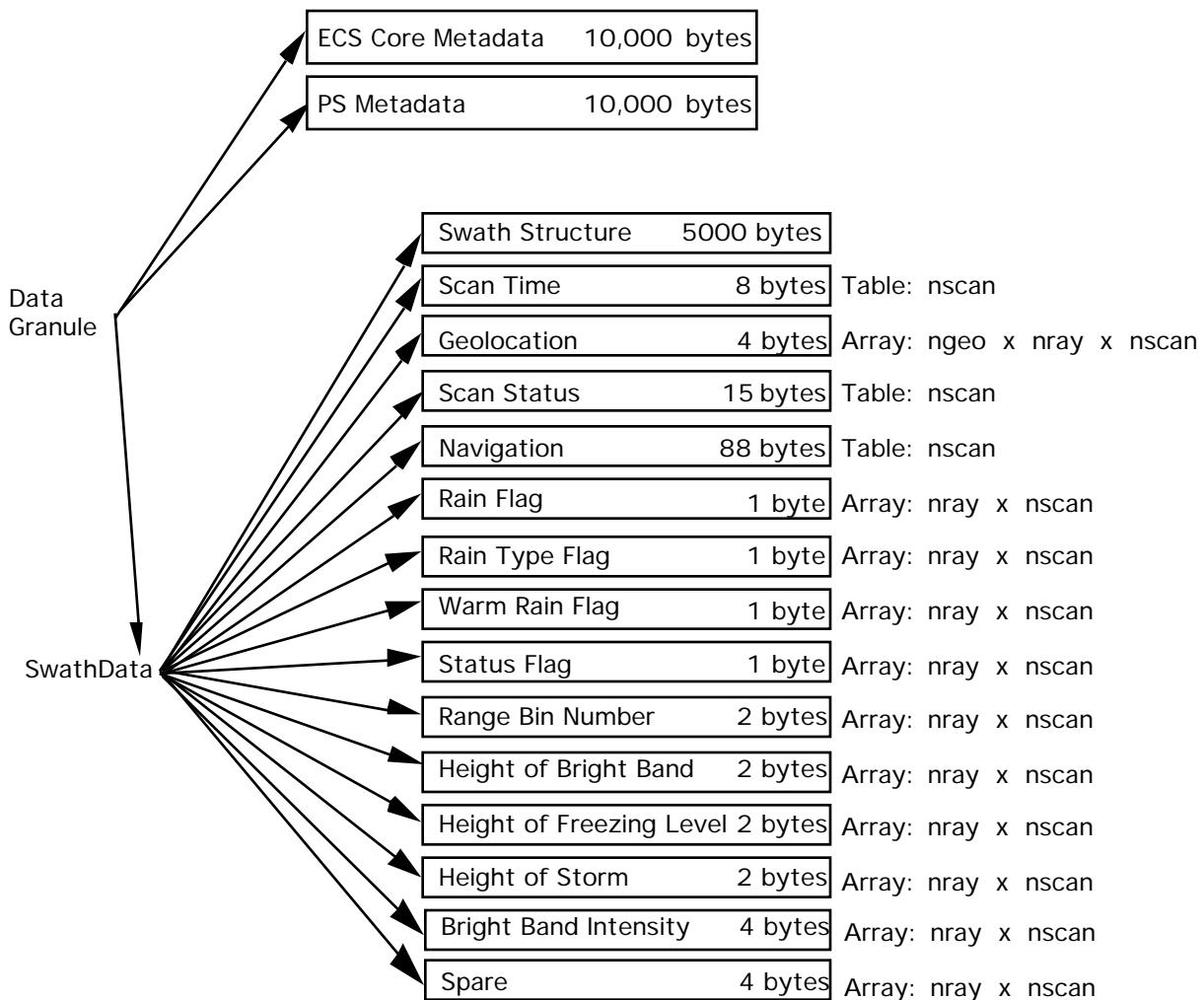


Figure 2.13-1
Data Format Structure for 2A-23, PR Qualitative

2.14 2A-25

One file of 2A-25, PR Profile, contains vertical rainfall rate profiles for one orbit. Also provided are: attenuation corrected Z profiles, parameters of Z-R relationships, integrated rainfall rate for each ray, range bin numbers of rain layer boundaries, and many intermediate parameters.

Contact Dr. Toshio Iguchi at Communications Research Laboratory/Kashima Space Research Center. Figure 2.14-1 shows the structure of 2A-25. The following sizing parameters are used:

- nscan = the number of scans within one granule (9150, on average)
- nray = the number of rays (49)
- ngeo = the number of geolocation data (2)
- ncell1 = the number of radar range cells at which rain rate is estimated (80)
- ncell2 = the number of radar range cells at which Z-R parameters are given (5)
- nmeth = the number of methods used (2)

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

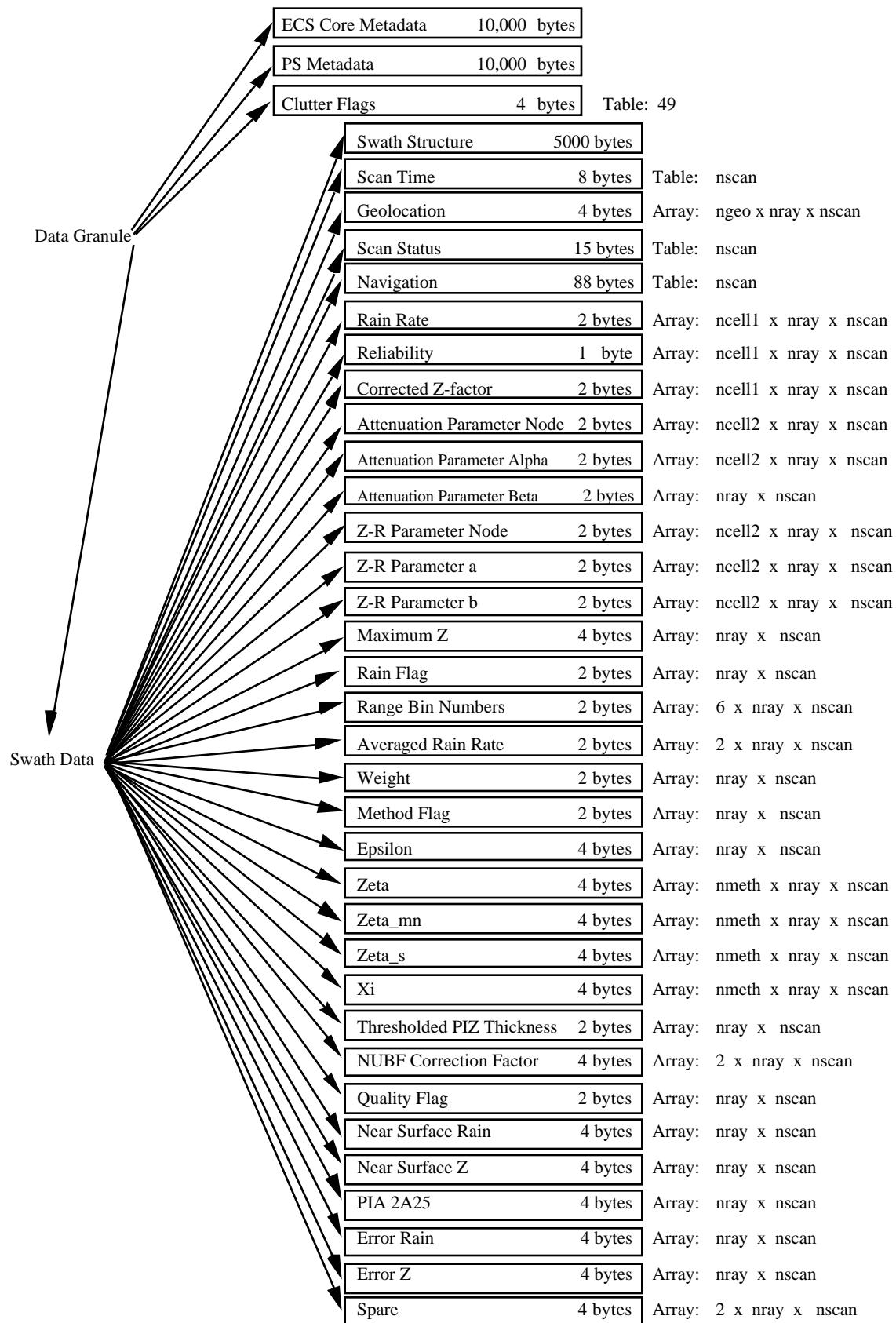


Figure 2.14-1
 Data Format Structure for 2A-25, PR Profile

2.15 2B-31

One file of 2B-31, TRMM Combined, contains vertical hydrometeor profiles for one orbit derived from PR radar and the 10 GHz channels of the TMI. Also provided are: the correlation-corrected mass-weighted mean drop diameter, the correlation-corrected relative spread of mass-weighted mean drop diameter, the correction made to the input path-attenuation estimate and their standard deviations.

Contact Dr. Ziad Haddad at NASA/Jet Propulsion Laboratory. Figure 2.15-1 shows the structure of 2B-31. The following sizing parameters are used:

- nscan = the number of scans within one granule (9150, on average)
- nray = the number of rays (49)
- ngeo = the number of geolocation data (2)
- Nradarrange = the number of radar range gates, up to about 20 km above the earth ellipsoid (80)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

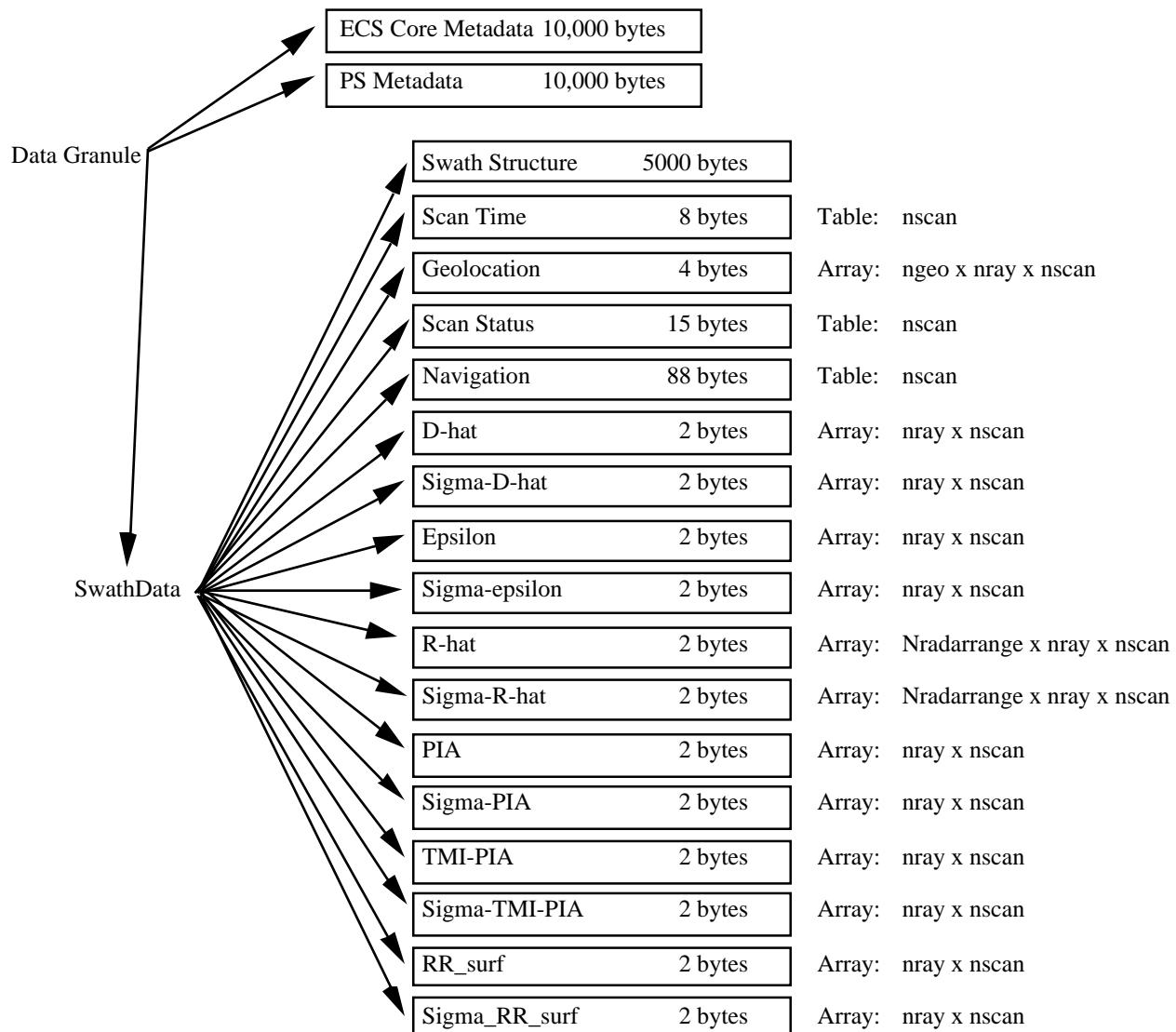


Figure 2.15-1
 Data Format Structure for 2B-31, TRMM Combined

2.16 2A-52

One file of 2A-52, Existence, contains the fraction of the GV radar Field of View (FOV) which has measurable precipitation, for one or more volume scans during one hour. The FOV is defined as the lowest sweep. The output is in ASCII format and thus not the subject of this tutorial.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology.

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

2.17 2A-53

One file of 2A-53, Radar Site Rain Map, contains instantaneous surface rainfall rate maps with a 2 km horizontal resolution for one or more volume scans during one hour.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology. Figure 2.17-1 shows the structure of 2A-53. The following sizing parameters are used:

- nvol: the number of volume scans within one granule
- nx_prod: the number of points in the x-dimension (151 for single radar sites, 363 for the Texas multiple radar site, and 257 for the Florida multiple radar site). The x-dimension is approximately east-west.
- ny_prod: the number of points in the y-dimension (151 for single radar sites, 285 for the Texas multiple radar site, and 353 for the Florida multiple radar site). The y-dimension is approximately north-south.

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

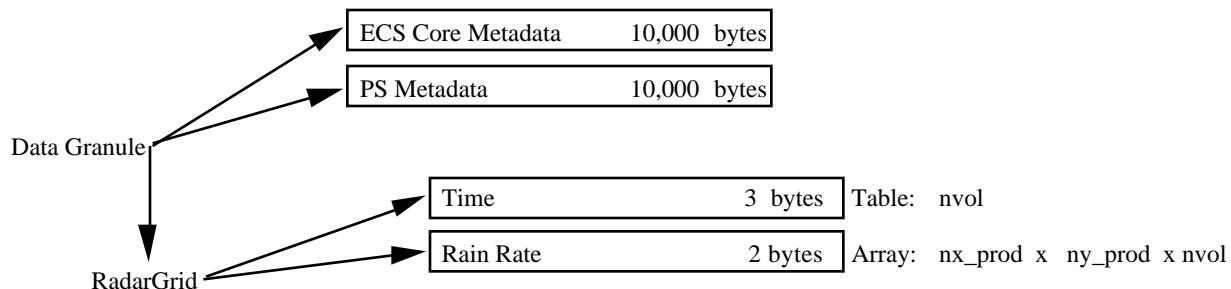


Figure 2.17-1
Data Format Structure for 2A-53, Radar Site Rain Map.

2.18 2A-54

One file of 2A-54, Radar Site Convective/Stratiform Map, contains instantaneous rain type maps with a 2 km horizontal resolution for one or more volume scans during one hour.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology. Figure 2.18-1 shows the structure of 2A-54. The following sizing parameters are used:

- nvol: the number of volume scans within one granule
- nx_prod: the number of points in the x-dimension (151 for single radar sites, 363 for the Texas multiple radar site, and 257 for the Florida multiple radar site). The x-dimension is approximately east-west.

- ny_prod: the number of points in the y-dimension (151 for single radar sites, 285 for the Texas multiple radar site, and 353 for the Florida multiple radar site). The y-dimension is approximately north-south.

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

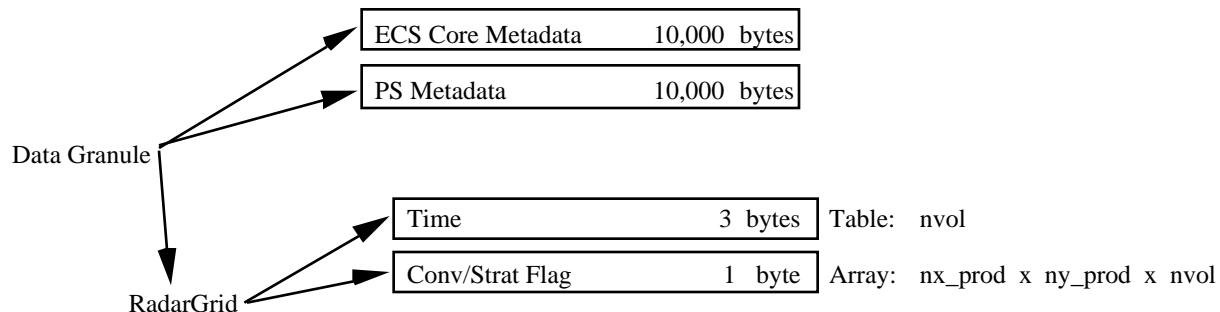


Figure 2.18-1
Data Format Structure for 2A-54, Radar Site Convective/Stratiform Map

2.19 2A-55

One file of 2A-55, Radar Site 3-D Reflectivities, contains 3 types of fields with a 1.5 km vertical resolution for one or more volume scans during one hour. The fields are 3 dimensional reflectivity with a horizontal resolution of 2 km, various vertical profiles based on the reflectivity, and Contoured Frequency by Altitude Diagram (CFAD) data.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology. Figure 2.19-1 shows the structure of 2A-55. The following sizing parameters are used:

- nvol: the number of volume scans within one granule
- nx_prod: the number of points in the x-dimension (151 for single radar sites, 363 for the Texas multiple radar site, and 257 for the Florida multiple radar site). The x-dimension is approximately east-west.
- ny_prod: the number of points in the y-dimension (151 for single radar sites, 285 for the Texas multiple radar site, and 353 for the Florida multiple radar site). The y-dimension is approximately north-south.
- nz: the number of points in the z-dimension (13)
- ncat: the number of categories for computing vertical profiles and CFADs (12)
- nbins: the maximum number of reflectivity bins (86)

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

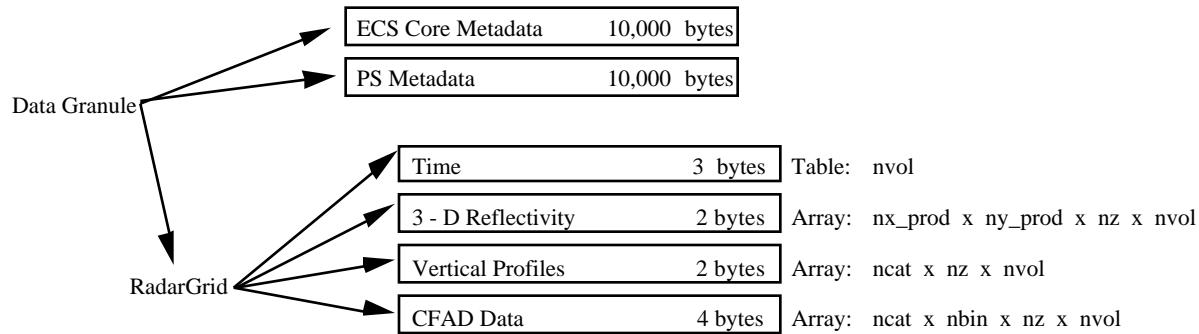


Figure 2.19-1
Data Format Structure for 2A-55, Radar Site 3-D Reflectivity

2.20 3A-11

One file of 3A-11, TMI Emission, contains $5^\circ \times 5^\circ$ monthly oceanic rainfall and freezing level. Statistics of the monthly rainfall are also included.

Contact Dr. Alfred Chang at NASA/GSFC. Figure 2.20-1 shows the structure of 3A-11. The following sizing parameters are used:

- nlat: the number of 5° grid intervals of latitude from 40° N to 40° S (16).
- nlon: the number of 5° grid intervals of longitude from 180° W to 180° E (72).

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

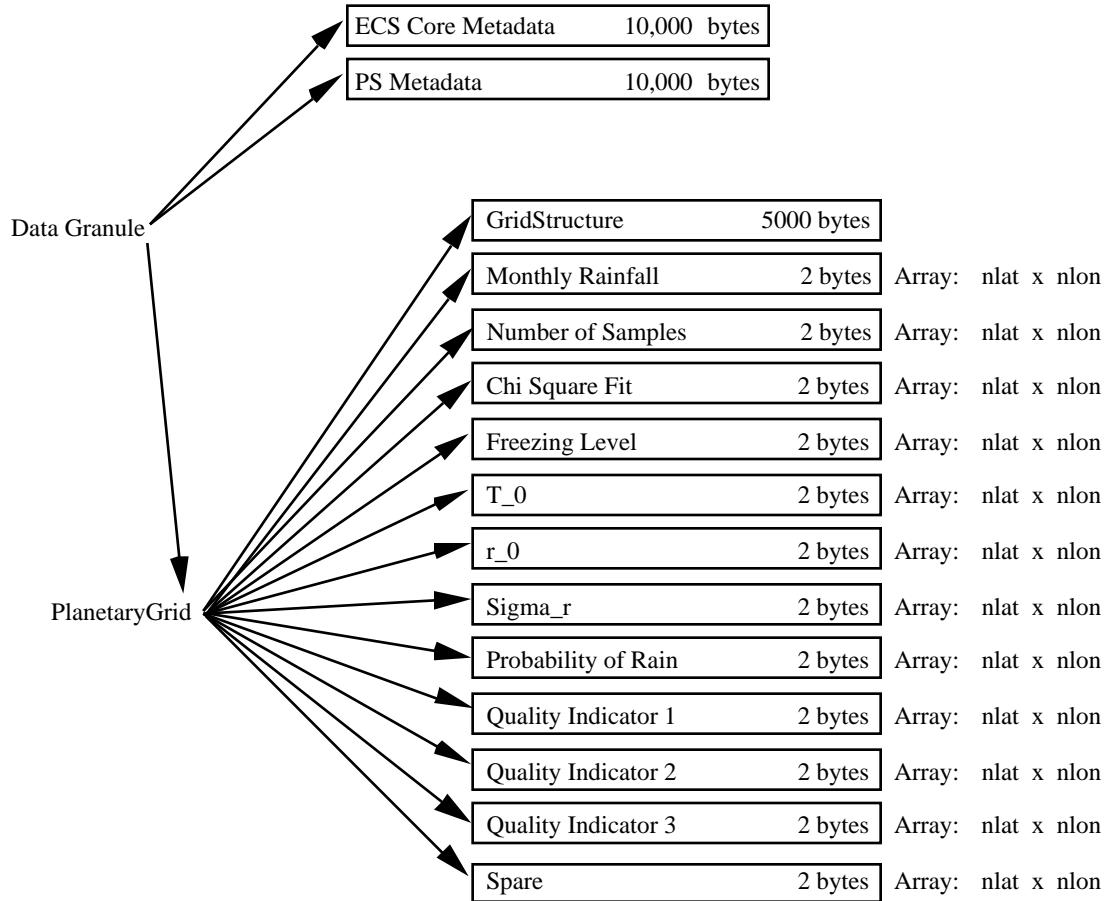


Figure 2.20-1
Data Format Structure for 3A-11, TMI Emission

2.21 3A-25

One file of 3A-25, PR Rainfall, contains $5^\circ \times 5^\circ$ and $0.5^\circ \times 0.5^\circ$ monthly statistics of PR measurements. The statistics include means, standard deviations, sample sizes, histograms, and correlation coefficients. The PR measurements include rainfall, reflectivity, Path-Integrated Attenuation (PIA), storm height, Xi, bright band height, snow-ice layer, and the Non-Uniform Beam Filling (NUBF) correction.

Contact Dr. Robert Meneghini at NASA/GSFC. Figure 2.21-1 shows the structure of 3A-25. The following sizing parameters are used:

- nlat: the number of 5° grid intervals of latitude from 40° N to 40° S (16).
- nlon: the number of 5° grid intervals of longitude from 180° W to 180° E (72).
- nlath: the number of 0.5° grid intervals of latitude from 37° N to 37° S (148).
- nlonh: the number of 0.5° grid intervals of longitude 180° W to 180° E (720).
- nh1: the number of fixed heights above the earth ellipsoid, at 2, 4, 6, 10, and 15 km plus one for path-average (6).

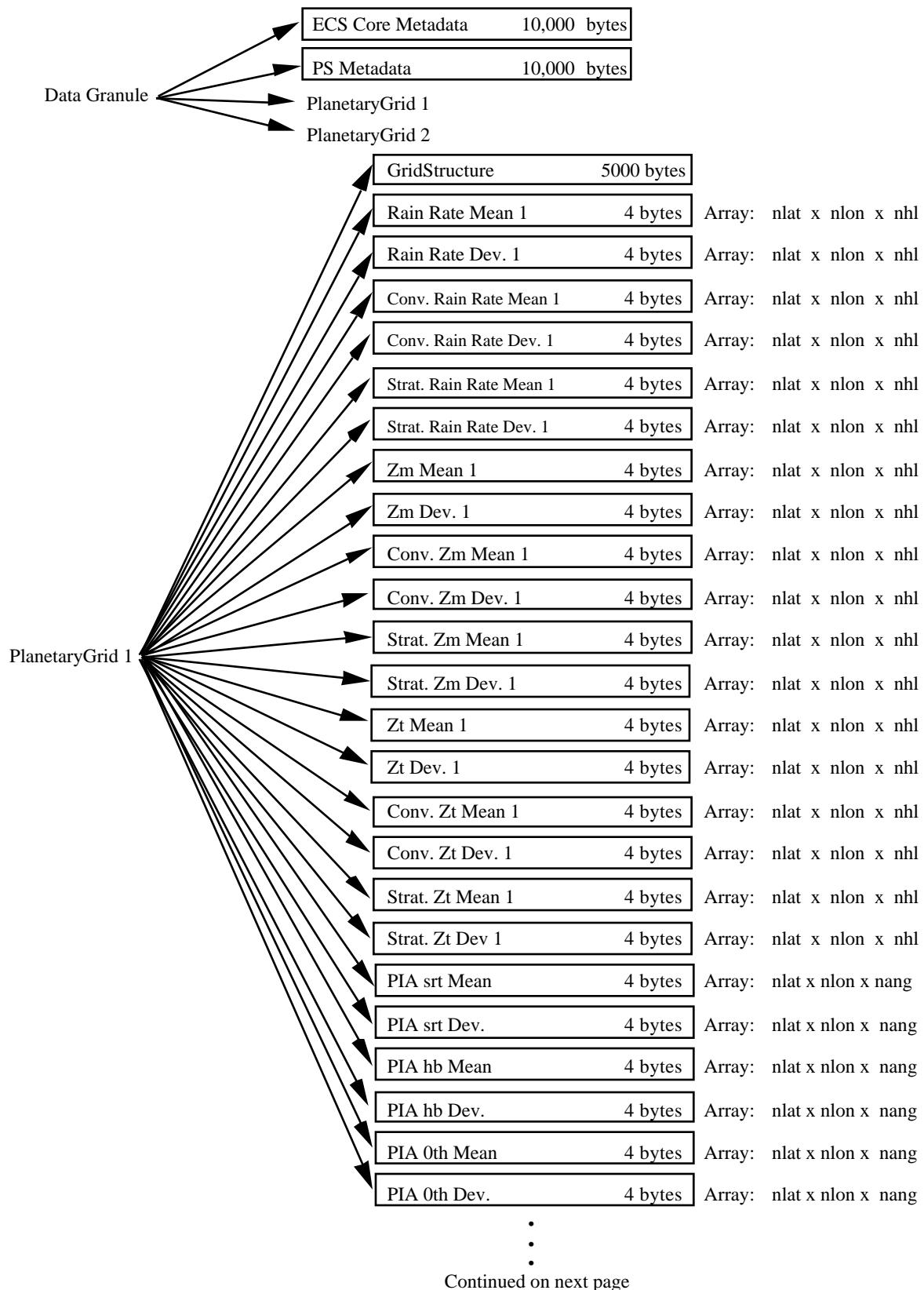


Figure 2.21-1
 Data Format Structure for 3A-25, PR Rainfall

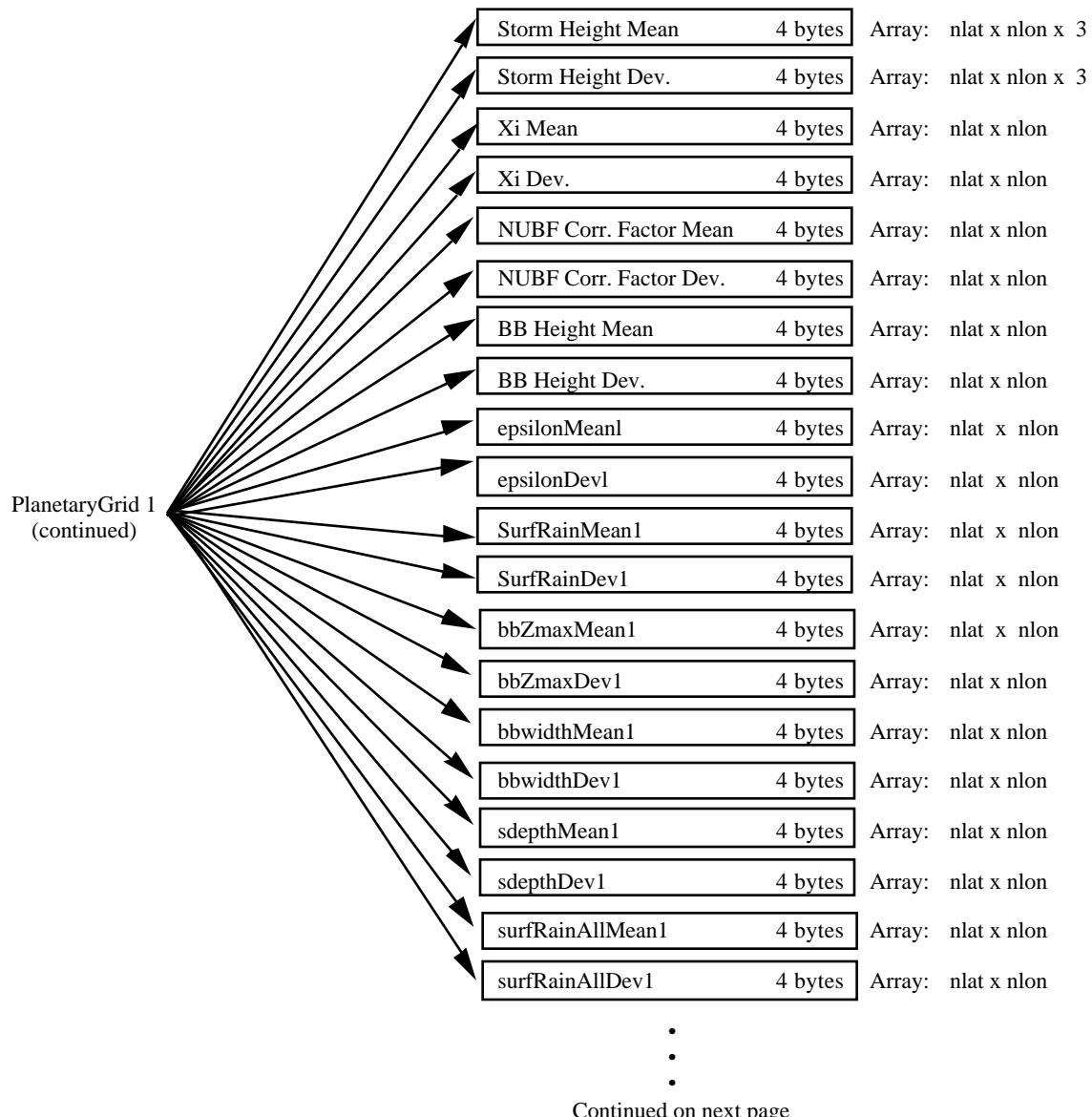


Figure 2.21-1
Data Format Structure for 3A-25, PR Rainfall (continued)

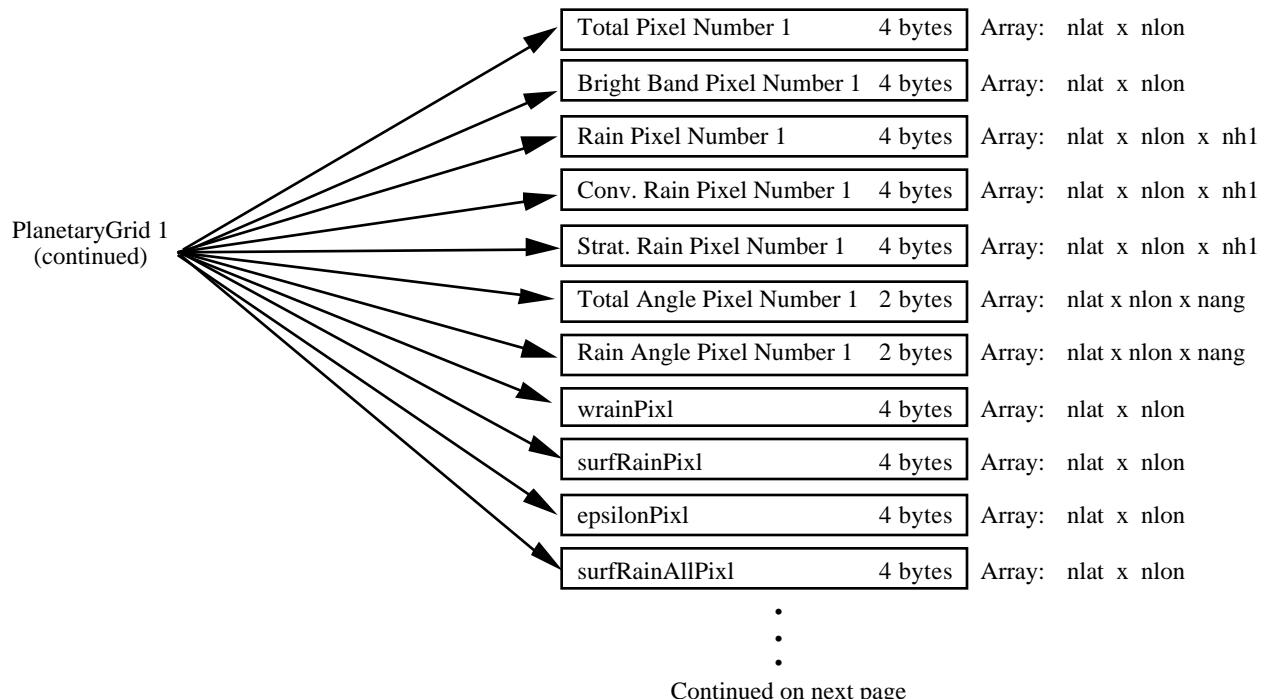


Figure 2.21-1 (continued)
Data Format Structure for 3A-25, PR Rainfall

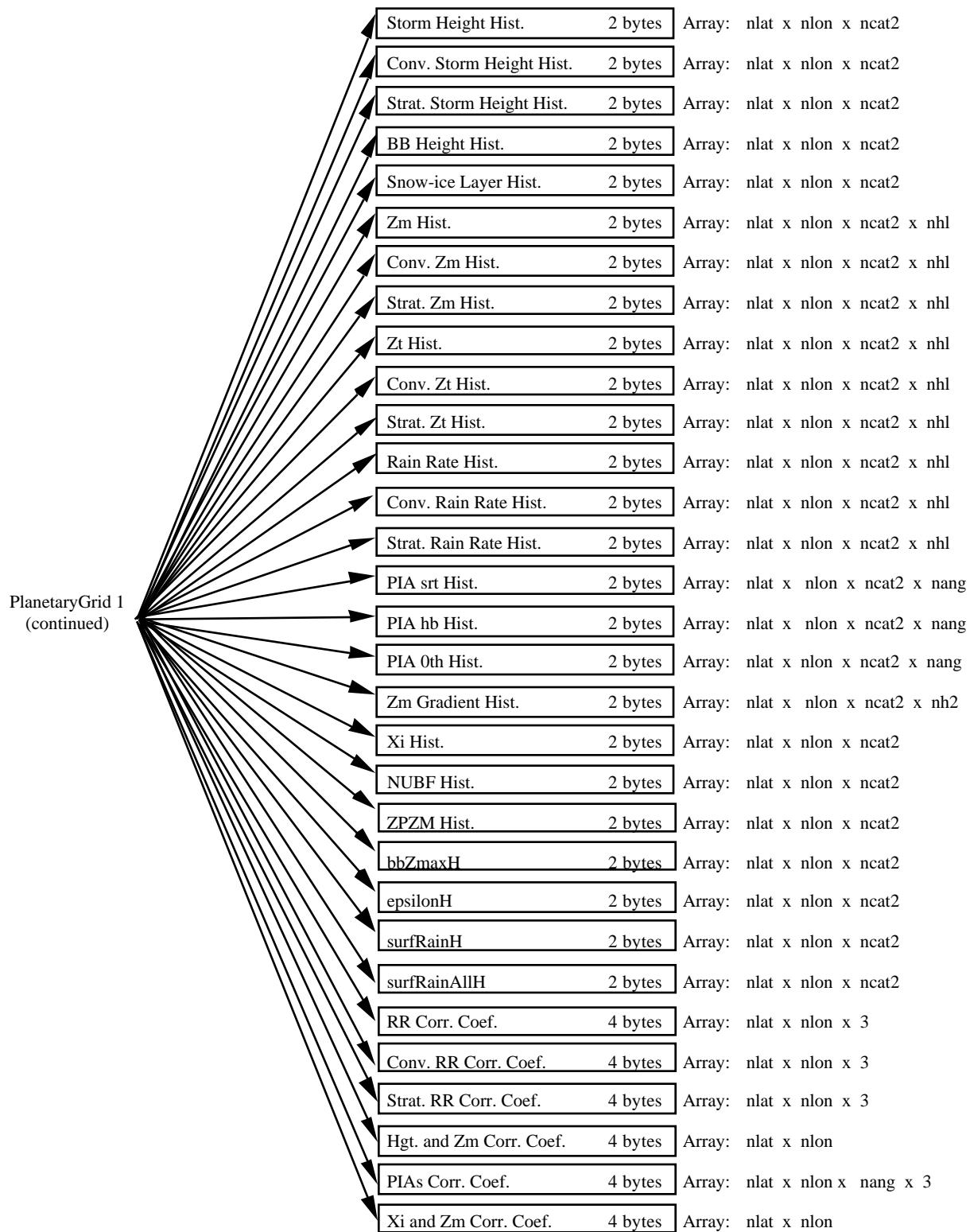


Figure 2.21-1 (continued)
Data Format Structure for 3A-25, PR Rainfall

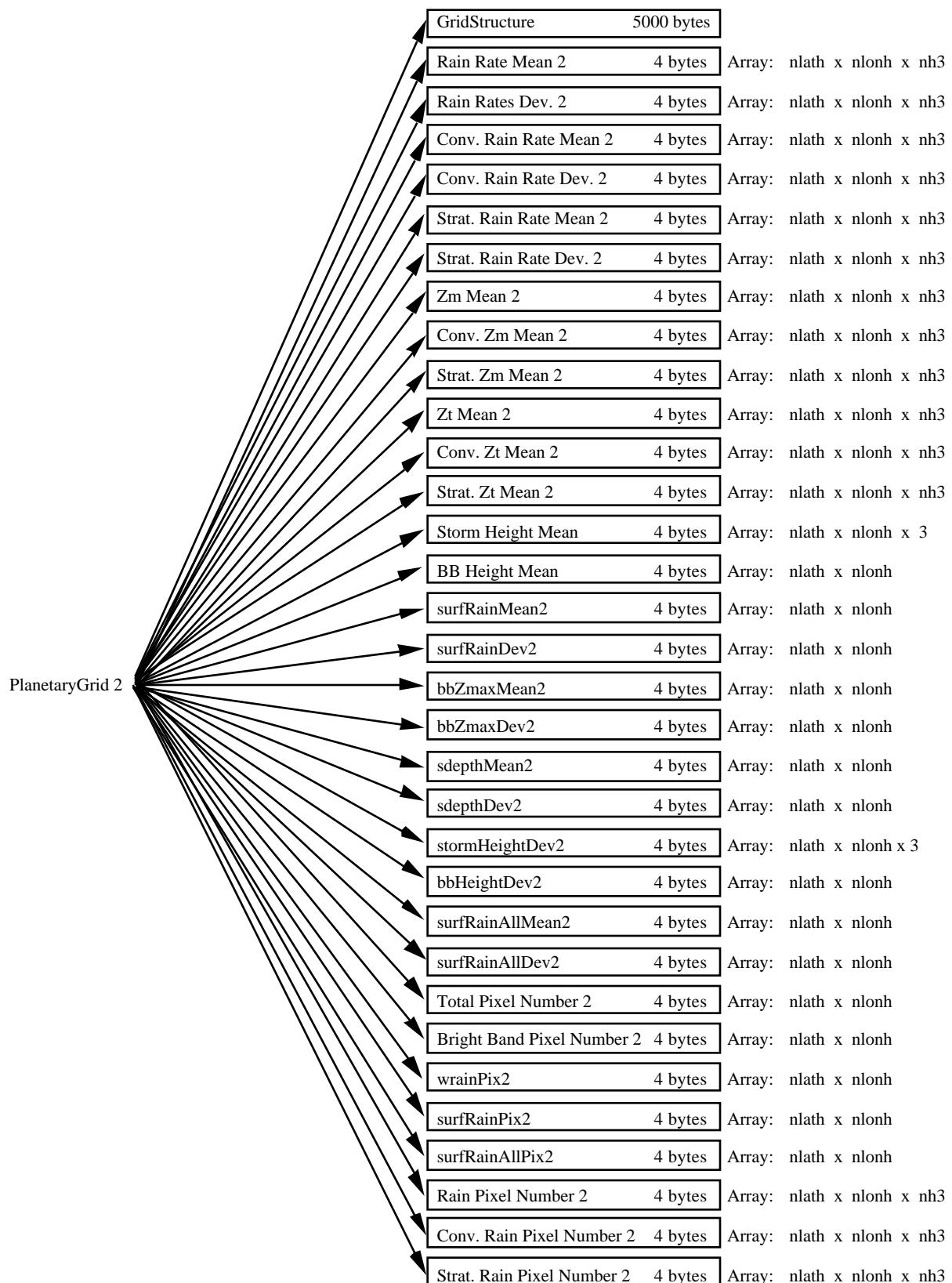


Figure 2.21-1 (continued)
Data Format Structure for 3A-25, PR Rainfall

- nh2: the number of fixed heights above the earth ellipsoid, at 2, 4, and 6 km (3).
- nh3: the number of fixed heights above the earth ellipsoid, at 2, 4, and 6 km plus one for path-average (4).
- ncat2: the second number of categories for histograms (30). Note that the number of thresholds is one greater than the number of categories. Thresholds are given below for several variables, others are **TBD**.

Reflectivity (dBZ) (bhz):

0.01, 12., 14., 16., 18., 20., 22., 24., 26., 28., 30., 32., 34., 36., 38., 40., 42., 44., 46., 48., 50., 52., 54., 56., 58., 60., 62., 64., 66., 68., 70.

Bright Band Height (km) (bhbb):

0.01, 0.25, 0.5, 0.75, 1., 1.25, 1.5, 1.75, 2., 2.25, 2.5, 2.75, 3., 3.25, 3.5, 3.75, 4., 4.25, 4.5, 4.75, 5., 5.25, 5.5, 5.75, 6., 6.25, 6.5, 6.75, 7., 7.5, 20.

Storm Height (km) (bhstorm):

0.01, 0.5, 1., 1.5, 2., 2.5, 3., 3.5, 4., 4.5, 5., 5.5, 6., 6.5, 7., 7.5, 8., 8.5, 9., 9.5, 10., 10.5, 11., 11.5, 12., 12.5, 13., 14., 15., 16., 20.

Snow Depth (km) (bhdepth):

0.01, 0.5, 0.75, 1., 1.25, 1.5, 1.75, 2., 2.25, 2.5, 2.75, 3., 3.25, 3.5, 3.75, 4., 4.25, 4.5, 4.75, 5., 5.25, 5.5, 5.75, 6., 6.25, 6.5, 6.75, 7., 7.25, 7.5, 20.

Zpzm (km) (bhzpzm):

0., 1., 2., 3., 4., 5., 6., 7., 8., 9., 10., 11., 12., 13., 14., 15., 16., 17., 18., 19., 20., 22., 24., 26., 28., 30., 32., 34., 36., 38., 50.

All PIA (dB) (bhpi):

0.01, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10., 100.

NUBF or Non-Uniform Beam Filling Factor (unitless) (bhnubf):

1., 1.05, 1.1, 1.15, 1.2, 1.25, 1.3, 1.35, 1.4, 1.45, 1.5, 1.55, 1.6, 1.65, 1.7, 1.75, 1.8, 1.85, 1.9, 1.95, 2., 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0

Xi or Horizontal Non-Uniformity Parameter (unitless) (bhxi):

0., 0.2, 0.4, 0.6, 0.8, 1., 1.2, 1.4, 1.6, 1.8, 2., 2.2, 2.4, 2.6, 2.8, 3., 3.2, 3.4, 3.6, 3.8, 4., 4.2, 4.4, 4.6, 4.8, 5., 10., 20., 30., 50., 10000.

Epsilon conditioned on use of SRT (unitless) (bhepsilon):

0., 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1., 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2., 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3.0

- nang: the number of fixed incidence angles, at 0° , 5° , 10° and 15° (4).

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

2.22 3A-26

One file of 3A-26, Surface Rain, contains $5^\circ \times 5^\circ$ monthly rainfall statistics computed by the multiple threshold method.

Contact Dr. Robert Meneghini at NASA/GSFC. Figure 2.22-1 shows the structure of 3A-26. The following sizing parameters are used:

- nlat: the number of 5° grid intervals of latitude from 40° N to 40° S (16).
- nlon: the number of 5° grid intervals of longitude from 180° W to 180° E (72).
- nh3: the number of fixed heights above the earth ellipsoid, at 2, 4, and 6 km plus one for path-average (4).
- ncat3: the number of categories for probability distribution functions (25).

Rain rate thresholds (mm/hr) are:

12., 14., 16., 18., 20., 22., 24., 26., 28., 30., 32., 34., 36., 38., 40., 42., 44., 46., 48.,
50., 52., 54., 56., 58., 60.

- nthrsh: the number of thresholds used for probability distribution functions (6).

Q-thresholds for Zero order:

0.1, 0.2, 0.3, 0.5, 0.75, 50.

Q-thresholds for HB:

0.1, 0.2, 0.3, 0.5, 0.75, 0.9999

pia-thresholds for SRT:

1.5, 1., 0.8, 0.6, 0.4, 0.1

More details of the format may be found on the WWW at
<http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

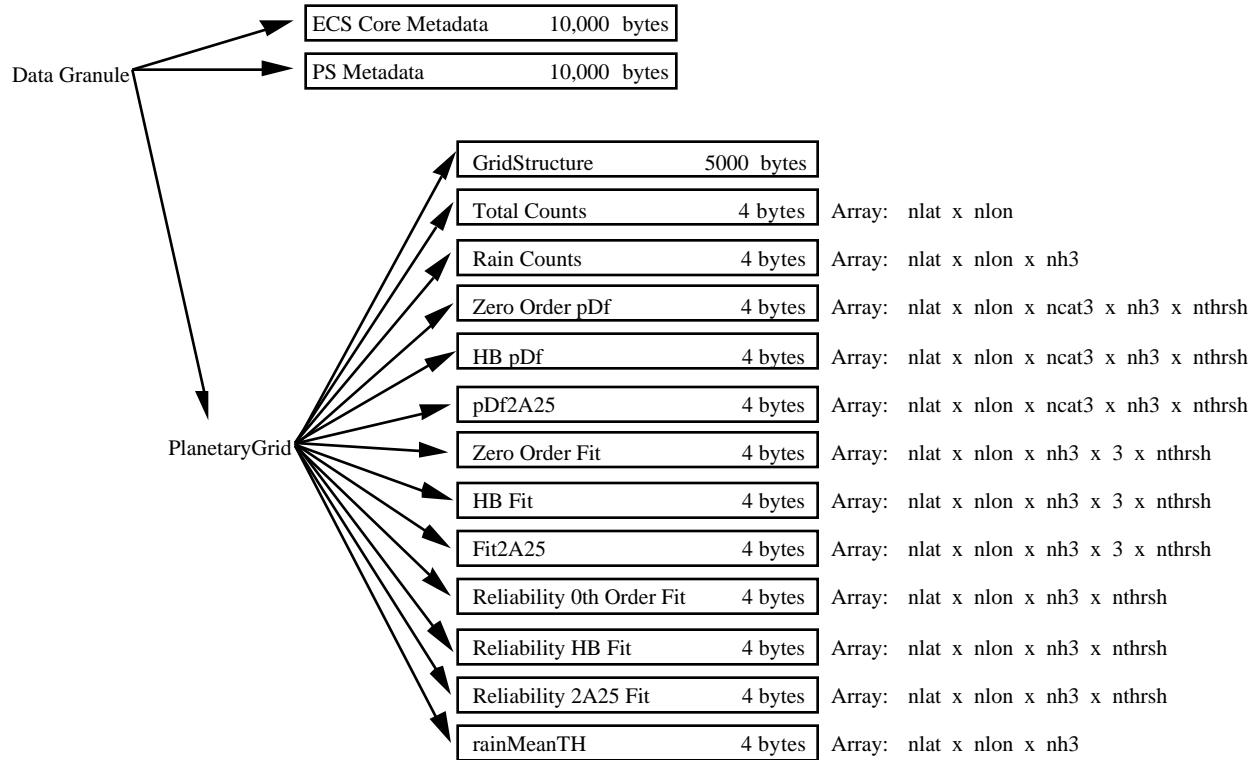


Figure 2.22-1
Data Format Structure for 3A-26, Surface Rainfall.

2.23 3B-31

One file of 3B-31, Rainfall Combined, contains $5^\circ \times 5^\circ$ monthly rainfall, adjustment ratio, and hydrometeor profiles.

Contact Dr. Christian Kummerow at NASA/GSFC. Figure 2.23-1 shows the structure of 3B-31. The following sizing parameters are used:

- nlat: the number of 5° grid intervals of latitude from 40° N to 40° S (16).
- nlon: the number of 5° grid intervals of longitude 180° W to 180° E (72).
- nlayer: the number of profiling layers (14).

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

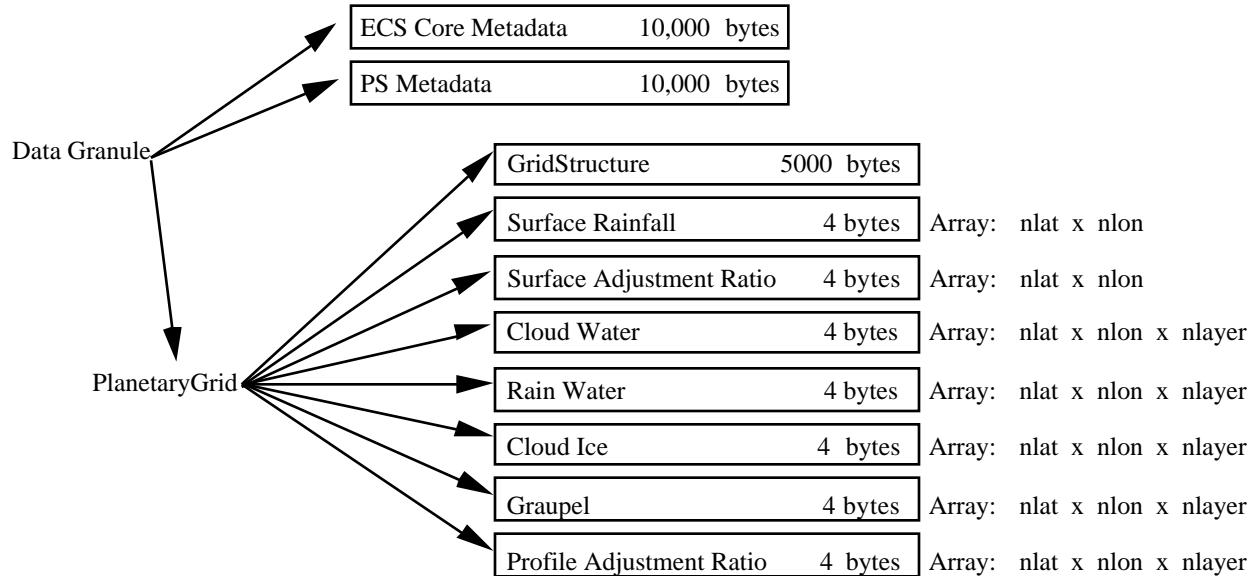


Figure 2.23-1
Data Format Structure for 3B-31, Rainfall Combined.

2.24 3B-42

One file of 3B-42, TRMM and Others GPI Calibration, contains $1^\circ \times 1^\circ$ pentad surface precipitation rate from the TRMM Combined Product 3B-31 and geosynchronous Infrared (IR).

Contact Dr. George Huffman at NASA/GSFC. Figure 2.24-1 shows the structure of 3B-42. The following sizing parameters are used:

- nlat: the number of 1° grid intervals of latitude from 40° N to 40° S (80).
- nlon: the number of 1° grid intervals of longitude 180° W to 180° E (360).

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

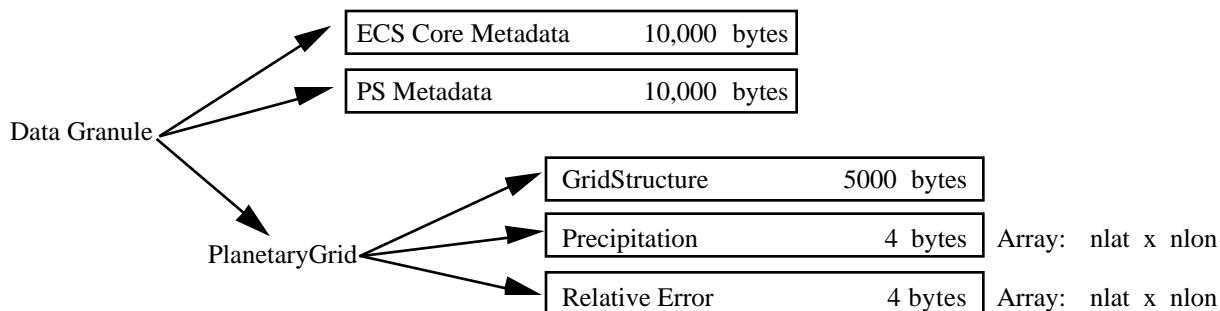


Figure 2.24-1
Data Format Structure for 3B-42, TRMM and Others GPI Calibration

2.25 3B-43

One file of 3B-43, TRMM and Others Data Sources, contains $1^{\circ} \times 1^{\circ}$ monthly surface precipitation rate from the TRMM Combined Product 3B-31, geosynchronous IR, Special Sensor Microwave/Imager (SSM/I) microwave, and rain gauges.

Contact Dr. George Huffman at NASA/GSFC. Figure 2.25-1 shows the structure of 3B-43. The following sizing parameters are used:

- nlat: the number of 1° grid intervals of latitude from 40° N to 40° S (80).
- nlon: the number of 1° grid intervals of longitude 180° W to 180° E (360).

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

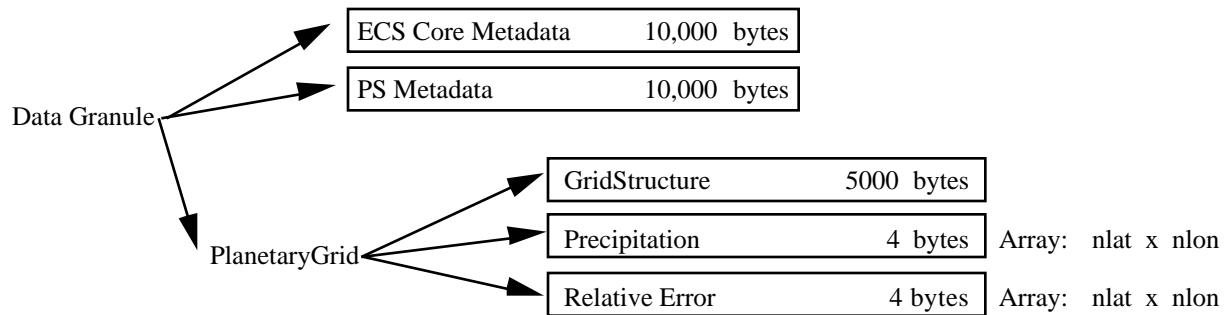


Figure 2.25-1
Data Format Structure for 3B-43, TRMM and Other Data Sources

2.26 3A-46

One file of 3A-46, SSM/I Rain, contains $1^{\circ} \times 1^{\circ}$ monthly surface rainfall rate maps from SSM/I data.

Contact Dr. George Huffman at NASA/GSFC. Figure 2.26-1 shows the structure of 3A-46. The following sizing parameters are used:

- nlat: the number of 1.0° grid intervals of latitude from 90° N to 90° S (180).
- nlon: the number of 1.0° grid intervals of longitude (360).

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

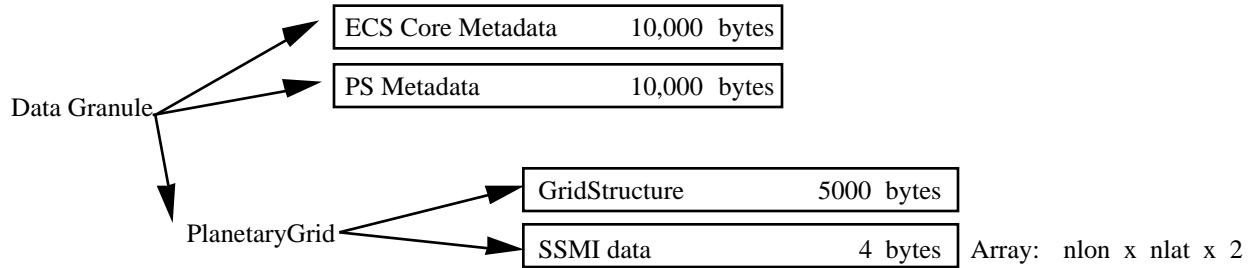


Figure 2.26-1
Data Format Structure for 3A-46, SSM/I Rain.

2.27 3A-53

One file of 3A-53, 5-day Site Rain Map, contains pentad surface rainfall rate maps with a 2 km horizontal resolution.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology. Figure 2.27-1 shows the structure of 3A-53. The following sizing parameters are used:

- nx_prod: the number of points in the x-dimension (151 for single radar sites, 363 for the Texas multiple radar site, and 257 for the Florida multiple radar site). The x-dimension is approximately east-west.
- ny_prod: the number of points in the y-dimension (151 for single radar sites, 285 for the Texas multiple radar site, and 353 for the Florida multiple radar site). The y-dimension is approximately north-south.

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

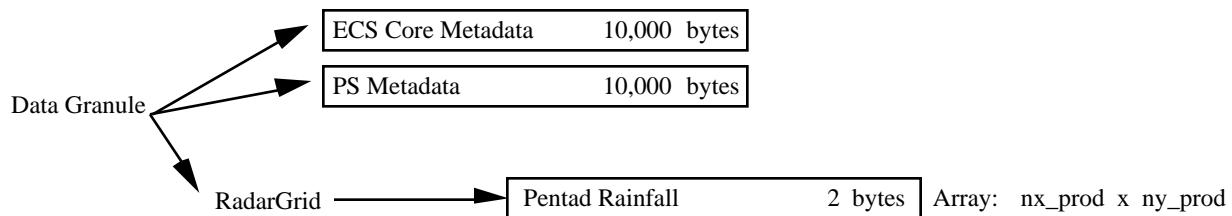


Figure 2.27-1
Data Format Structure for 3A-53, 5-Day Site Rain Map

2.28 3A-54

One file of 3A-54, Site Rain Map, contains monthly surface rainfall rate maps with a 2 km horizontal resolution.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology. Figure 2.28-1 shows the structure of 3A-54. The following sizing parameters are used:

- nx_prod: the number of points in the x-dimension (151 for single radar sites, 363 for the Texas multiple radar site, and 257 for the Florida multiple radar site). The x-dimension is approximately east-west.
- ny_prod: the number of points in the y-dimension (151 for single radar sites, 285 for the Texas multiple radar site, and 353 for the Florida multiple radar site). The y-dimension is approximately north-south.

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

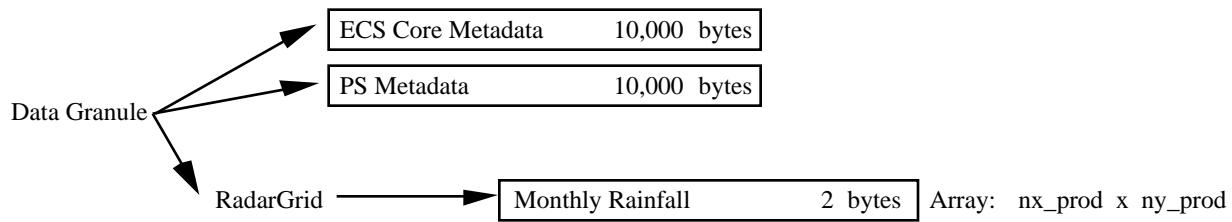


Figure 2.28-1
Data Format Structure for 3A-54, Site Rainfall Map.

2.29 3A-55

One file of 3A-55, Monthly 3-D Structure, contains radar site monthly vertical reflectivity statistics.

Contact Dr. Michael Biggerstaff at Texas A&M University/Dept. of Meteorology. Figure 2.29-1 shows the structure of 3A-55. The following sizing parameters are used:

- nz: the number of points in the z-dimension (13)
- ncat: the number of categories for computing vertical profiles and CFADs (12)
- nbin: the maximum number of reflectivity bins (86)

More details of the format may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

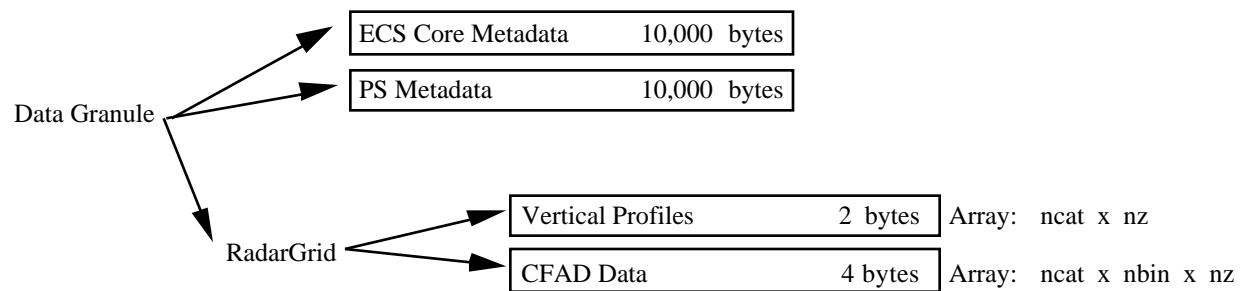


Figure 2.29-1
Data Format Structure for 3A-55, Monthly 3-D Structure.

3. READING TRMM DATA PRODUCTS

This section includes three example programs to read a TRMM data product in HDF format. The first program is written in C using the TSDIS Toolkit. The second program is written in C using HDF routines. The third program is written in Interactive Data Language (IDL) using IDL routines. The TSDIS Toolkit applies the correct factors and biases and handles flags to correctly unpack the data. To use direct HDF or IDL, a program should apply the scaling factors and biases and handle flags (in our example, the missing data flag). The scaling factors, biases, and flags are specified in the file specifications. All approaches need the names of the variables. With the Toolkit, the names are in an include file. With direct HDF or IDL, the program can read the names or the names could be read from a Toolkit include file. To allow comparison, all the example programs were run on the same data product and print out the same variables. The data product is a subsetted 2A-25 file, which is smaller than, but otherwise identical to, the standard 2A-25 file. Program source code, date files, and Toolkit software and documentation are available on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>.

3.1 TSDIS TOOLKIT READ FROM C

The C program below reads one SDS, the rain rate SDS, and prints one ray of data from that SDS. The Toolkit automatically handles scaling and the missing data flag. Finally the program reads one Vdata, Scan Status, and prints one of the Scan Status fields, Fractional Orbit Number. The names of the variables are listed in the Input/Output (IO) include files supplied with the Toolkit. In our example, IO_PR.h is included in the program and lists the variable names.

3.1.1 Program Source Code

```
*****  
TK_read.c
```

```
DISCLAIMER: This software is provided for users of TRMM data.  
TSDIS DOES NOT PROVIDE SUPPORT FOR THIS SOFTWARE.
```

The following program (TK_read.c) demonstrates how TSDIS 2A25 data can be read via the TSDIS toolkit.

Sample executions: TK_read 2A25_CSI.980812.4067.FLOR.3.HDF

```
It is assumed that a good 2A25 TRMM data file is being read.  
******/
```

```
#include "IO_PR.h"  
  
int status,nscan,scan,i;  
  
void main(int argc, char **argv)  
{  
    IO_HANDLE rHandle;  
    L2A_25_SWATHDATA dataScan;
```

```
printf("\n****OUTPUT for %s **** \n",argv[1]);  
  
status = TKopen ( argv[1], TKgetAlgorithmID ( argv[1] ),  
    TK_READ_ONLY, &rHandle );  
printf("\nStatus from TKopen: %d \n", status);  
status = TKreadMetadataInt (&rHandle, TK_ORBIT_SIZE, &nscan);  
printf("\nStatus and number of scans: %d %d\n", status,nscan);  
if (nscan == 0) printf("EMPTY GRANULE!!\n");  
  
for (scan = 0; scan < nscan; scan++)  
{  
    status = TKreadScan(&rHandle, &dataScan);  
  
    if (scan == 0)  
    {  
        printf("\nStatus from TKreadScan: %d \n", status);  
        printf("\n\nRainfall rate in mm/hr, profile for first scan, first  
ray(anglebin)\n");  
        printf("\nbins num      value\t bin num      value\t bin num      value\n");  
        for (i=0; i< 80; i++)  
        {  
            printf("(%d)\t ",i);  
            printf("%7.2f \t ", dataScan.rain[0][i]);  
            if (((i+1)%3 == 0)&&(i!=0))  
                printf("\n");  
        }  
  
        printf("\n\nGeolocation for first 10 rays of first scan\n");  
        printf("Lat.\t\t Lon.\n");  
        for (i=0; i< 10; i++)  
        {  
            printf("%f \t ", dataScan.geolocation[i][0]);  
            printf("%f \t \n", dataScan.geolocation[i][1]);  
        }  
  
        printf("\nFractional Orbit Number, first 10 scans\n");  
        printf("Scan Number      Fractional Orbit Number\n");  
        printf("-----\n");  
    }  
  
    if (scan < 10) /* for scans 0 to 9 */  
    {  
        printf ("      %i\t\t%f\n", i, dataScan.scanStatus.fractOrbitN);  
    }  
}  
status = TKclose(&rHandle);  
printf("\nStatus from TKclose: %d \n", status);  
printf("\n\t the end :-) \n\n");  
}
```

3.1.2 Build and Run

- Download and install HDF. HDF software and documentation can be retrieved from the following ftp site: [ftp.ncsa.uiuc.edu](ftp://ftp.ncsa.uiuc.edu).
- Download and install the TSDIS Toolkit. Software and documentation can be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>
- The program to read the HDF product should contain one include file, depending on the product read:

Product	Include File
PR, 2B31, 3B31	IO_PR.h
1B11, 2A12, 3A11	IO_TMI.h
1B01, 3B42, 3B43	IO_VIRS.h
GV, 3A46	IO_GV.h

- Set environmental variables to the HDF include directory, the HDF library directory, and the TSDIS Toolkit directory, if not already set. For example:

```
setenv HDF_INC /data/hdf/hdf4.0r2_n32/include  
setenv HDF_LIB /data/hdf/hdf4.0r2_n32/lib  
setenv TSDISTK /develop2/people/stout/toolkit_4.7
```

- Compile and Load. The -n32 option below should be used only if HDF and the Toolkit were also compiled with -n32.

```
cc -n32 -o TK_read TK_read.c -I$HDF_INC -I$TSDISTK/include \  
-L$HDF_LIB -L$TSDISTK/lib -ltsdistk -lmfhdf -ldf -lz -lm
```

- Run program

```
TK_read 2A-25_CSI.980812.4067.FLOR.3.HDF
```

3.1.3 Output

```
****OUTPUT for 2A25_CSI.980812.4067.FLOR.3.HDF ****  
  
Status from TKopen: 0  
  
Status and number of scans: 0 320  
  
Status from TKreadScan: 0  
  
Rainfall rate in mm/hr, profile for first scan, first ray(anglebin)
```

bin num	value	bin num	value	bin num	value
(0)	0.00	(1)	0.00	(2)	0.00
(3)	0.00	(4)	0.00	(5)	0.00
(6)	0.00	(7)	0.00	(8)	0.00
(9)	0.00	(10)	0.00	(11)	0.00
(12)	0.00	(13)	0.00	(14)	0.00
(15)	0.00	(16)	0.00	(17)	0.00
(18)	0.00	(19)	0.00	(20)	0.00
(21)	0.00	(22)	0.00	(23)	0.00
(24)	0.00	(25)	0.00	(26)	0.00
(27)	0.00	(28)	0.00	(29)	0.00
(30)	0.00	(31)	0.00	(32)	0.00
(33)	0.00	(34)	0.00	(35)	0.00
(36)	0.00	(37)	0.00	(38)	0.00
(39)	0.00	(40)	0.20	(41)	0.50
(42)	0.40	(43)	0.40	(44)	0.40
(45)	1.00	(46)	2.40	(47)	4.60
(48)	5.10	(49)	5.10	(50)	4.40
(51)	5.30	(52)	10.70	(53)	9.70
(54)	12.20	(55)	11.70	(56)	13.40
(57)	8.70	(58)	6.90	(59)	5.10
(60)	4.30	(61)	5.10	(62)	3.70
(63)	2.90	(64)	2.30	(65)	2.00
(66)	1.60	(67)	1.20	(68)	1.00
(69)	0.80	(70)	0.60	(71)	1.00
(72)	0.90	(73)	-88.90	(74)	-88.90
(75)	-88.90	(76)	-88.90	(77)	-88.90
(78)	-88.90	(79)	-88.90		

Geolocation for first 10 rays of first scan

Lat.	Lon.
31.464056	-88.948326
31.423845	-88.932983
31.383791	-88.917656
31.343937	-88.902374
31.304688	-88.887276
31.265430	-88.872147
31.226549	-88.857132
31.187859	-88.842155
31.149593	-88.827301
31.111242	-88.812393

Fractional Orbit Number, first 10 scans

Scan Number	Fractional Orbit Number
-------------	-------------------------

10	0.422187
10	0.422296
10	0.422406
10	0.422515
10	0.422625
10	0.422734
10	0.422843
10	0.422953
10	0.423062
10	0.423172

```
Status from TKclose: 0  
  
the end :-)
```

3.1.4 Error Files

This section may be skipped by the general user of TRMM data; it is only relevant to the use of a TRMM algorithm. Two error files are used by TSDIS and the TSDIS Toolkit. Both are output by a program run off-line by TSDIS staff. For example, for algorithm 2B-31, the files are TS_2B-31_37.h and TS_37. Both files should be placed in the \$TSDISTK/include directory before building the algorithm. TS_2B-31_37.h is an include file used in compiling the algorithm. TS_37 is used at run time if an error is encountered.

3.2 TSDIS TOOLKIT READ FROM FORTRAN

Using the TSDIS Toolkit from a FORTRAN program is similar to using the TSDIS Toolkit from a C program. See the documentation on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>. Note that the reading program should include these three include files:

IO_X.h, IO.h, and TKfortranDeclare.h

where IO_X.h is one of the four include files discussed in Section 3.1.2.

3.3 DIRECT HDF READ FROM C

The C program below lists the SDS and Vdata names within the 2A-25 data product. (The names are needed to read SDSs and Vdatas.) The program also reads one SDS, the rain rate SDS. The rain rate array is then unscaled and the missing data flag treated separately. Then the program prints one ray of data from that SDS. Finally the program reads one Vdata, Scan Status, and prints one of the Scan Status fields, Fractional Orbit Number.

3.3.1 Program Source Code

```
*****  
HDF_read.c  
  
DISCLAIMER: This software is provided for users of TRMM data.  
TSDIS DOES NOT PROVIDE SUPPORT FOR THIS SOFTWARE.
```

The following program demonstrates how TSDIS 2A-25 data can be read via HDF (Hierarchical Data Format) routines.

Hence we can see the SDS(multi-dimentional array) and Vdata(table) formats of HDF in the TSDIS data.

Sample executions:

HDF_read 2A-25_CSI.980812.4067.FLOR.3.HDF

It is assumed that a good 2A-25 TSDIS data file is being read.

Portions of this code were taken from the NCSA HDF User's Guide.

```
*****/*  
  
#include "hdf.h"  
  
typedef struct  
{  
    int8      missing;  
    int8      validity;  
    int8      qac;  
    int8      geoQuality;  
    int8      dataQuality;  
    int8      scOrient;  
    int8      acsMode;  
    int8      yawUpdateS;  
    int8      prMode;  
    int8      prStatus1;  
    int8      prStatus2;  
    float32   fractOrbitN;  
} PR_SCAN_STATUS;  
  
void main(int argc, char *argv[] )  
{  
    int32 sd_id, sds_id, n_datasets, n_fileAttrs,  
          rain_index, geo_index, index, status;  
    int32 dim_sizes[10];  
    int32 start[3];  
    int32 rank, num_type, attributes, istat;  
    char name[256];  
  
    /* note: ~9150 scans for a regular 2A-25 granule; ~325 for csi */  
    /* for simplicity we use 500 and therefore only read a subset */  
    /* of a regular granule */  
    int16 array_data[500][49][80];  
    float32 rain_out[500][49][80];  
    float32 array_data2[500][49][2];  
  
    char vdata_name[256];  
    char fields[256];  
    int32 file_id, vdata_id;  
    int32 n_records, interlace, vdata_size, vdata_ref;  
    int frac_orb_index;  
    int i,j,k;  
    uchar8 databuf[9000], *ptr;  
    float64      scanTime;
```

```
PR_SCAN_STATUS scanStatus;

/* Open the file and initiate the SD interface. */

sd_id = SDstart(argv[1], DFACC_RDONLY);

/* Determine the contents of the file. */
istat = SDfileinfo(sd_id, &n_datasets, &n_file_attrs);

printf("\n****OUTPUT for %s **** \n", argv[1]);
printf("\n***SDS ELEMENTS*** \nsds_name(rank): \n\n");

/* Access and print the name of every data set in the file. */
rain_index = -99;
for (index = 0; index < n_datasets; index++)
{
    sds_id = SDselect(sd_id, index);
    status = SDgetinfo(sds_id, name, &rank, dim_sizes, \
                        &num_type, &attributes);
    if (strcmp(name, "rain") == 0)
        rain_index = index;
    if (strcmp(name, "geolocation") == 0)
        geo_index = index;
    printf("%s", name);
    printf("(%i)\n", rank);
    istat = SDendaccess(sds_id);
}

sds_id = SDselect(sd_id, rain_index);
status = SDgetinfo(sds_id, name, &rank, dim_sizes, \
                    &num_type, &attributes);

/*only read the first 500 (or less) scans, not all ~9140° Scans */
dim_sizes[0] = 500;
start[0]=start[1]=start[2]=0;
istat = SDreaddata(sds_id, start, NULL, dim_sizes, (VOIDP)array_data );

/* UNPACK THE RAIN VARIABLE */
for (i=0; i<500; i++)
for (j=0; j<49; j++)
for (k=0; k<80; k++)
{
    switch (array_data[i][j][k])
    {
        case -9999: rain_out[i][j][k] = -9999.0; break;
        default:    rain_out[i][j][k] = array_data[i][j][k]/10.0; break;
    }
}

printf("\n Rainfall rate in mm/hr, profile for first scan, first
ray(anglebin)\n");
printf("\nbins num      value\t bin num      value\t bin num      value\n");
for (i=0; i< 80; i++)
{
```

```
printf("(%d)\t ",i);
printf("%7.2f \t ", rain_out[0][0][i]);
if (((i+1)%3 == 0)&&(i!=0))
    printf("\n");
}

sds_id = SDselect(sd_id, geo_index);
status = SDgetinfo(sds_id, name, &rank, dim_sizes, \
    &num_type, &attributes);
start[0]=start[1]=start[2]=0;
istat = SDreaddata(sds_id, start, NULL, dim_sizes, (VOIDP)array_data2 );
printf("\n\n Geolocation for first 10 rays of first scan\n");
printf("Lat.\t Lon.\n", array_data2[0][i][0]);
for (i=0; i< 10; i++)
{
    printf("%f \t ", array_data2[0][i][0]);
    printf("%f \t \n", array_data2[0][i][1]);
}

istat = SDendaccess(sds_id);

/* Terminate access to the SD interface. */
istat = SDend(sd_id);

/* Open the file and initiate the V interface. */
file_id = Hopen(argv[1], DFACC_RDONLY, 0);
Vstart(file_id);

printf ("\n\n*****VDATA ELEMENTS*** \n\n");

/* for all possible tables (vdatas) */
for (j = -1; j < 100; j++)
{
    vdata_ref = VSgetid(file_id, j);

    /* Attach to the first Vdata in read mode. */
    vdata_id = VSattach(file_id, vdata_ref, "r");

    for (i=0; i<256; i++)
        fields[i] = '\0';

    /* Get the list of field names. */
    istat = VSinquire(vdata_id, &n_records, &interlace,
        fields, &vdata_size, vdata_name);

    if (strstr(fields, "fractOrbitN"))
        frac_orb_index = j;
    if (vdata_size > 0)
        printf("vdata_name: %s\nfields: %s\nn_records: %d\nvdata_size: %d\n\n",
            vdata_name, fields, n_records, vdata_size);
    VSdetach(vdata_id);
}

vdata_ref = VSgetid(file_id, frac_orb_index);
```

```
/* Attach to the first Vdata in read mode. */
vdata_id = VSattach(file_id, vdata_ref, "r");

for (i=0; i<256; i++)
    fields[i] = '\0';

/* Get the list of field names. */
istat = VSinquire(vdata_id, &n_records, &interlace,
                   fields, &vdata_size, vdata_name);

VSsetfields (vdata_id, fields );
istat = VSread(vdata_id, databuf, n_records, FULL_INTERLACE);

ptr=databuf;

/*skip a whole PR_SCAN_STATUS structure block of memory */
ptr += sizeof(PR_SCAN_STATUS) - 1 ;

/*back up one field to fractOrbitN */
ptr -= sizeof(float32);

printf("Fractional Orbit Number, first 10 scans\n");
printf("Scan Number      Fractional Orbit Number\n");
printf("-----\n");
/* for scan 0 to 9 */
for (j = 0; j < 10; j++)
{
    /* extract the data we want */
    memcpy(&scanStatus.fractOrbitN, ptr,
           sizeof(scanStatus.fractOrbitN));

    printf ("      %i\t%f\n", j, scanStatus.fractOrbitN);

    ptr += sizeof(PR_SCAN_STATUS) - 1 ;
}

printf("\n\t the end :-)\n\n");

VSdetach(vdata_id);

/* Terminate access to the V interface and close the file. */
Vend(file_id);
Hclose(file_id);

}
```

3.3.2 Build and Run

- Download and install HDF. HDF software and documentation can be retrieved from the following ftp site: [ftp.ncsa.uiuc.edu](ftp://ftp.ncsa.uiuc.edu).
- Set environmental variables to the HDF include directory and the HDF library directory if not already set. For example:

```
setenv HDF_INC /data/hdf/hdf4.0r2_n32/include  
setenv HDF_LIB /data/hdf/hdf4.0r2_n32/lib
```

- Compile and load. The -n32 option below should be used only if HDF was compiled with -n32.

```
cc -n32 -o HDF_read HDF_read.c -I$HDF_INC \  
-L$HDF_LIB -lmfhdf -ldf -lz
```

- Execute the program

```
HDF_read 2A-25_CSI.980812.4067.FLOR.3.HDF
```

3.3.3 Output

```
*****OUTPUT for 2A-25_CSI.980812.4067.FLOR.3.HDF *****  
  
*****SDS ELEMENTS***  
sds_name(rank):  
  
geolocation(3)  
rain(3)  
reliab(3)  
correctZFactor(3)  
attenparmNode(3)  
attenParmAlpha(3)  
attenParmBeta(2)  
ZRParmNode(3)  
ZRParmA(3)  
ZRParmB(3)  
zmax(2)  
rainFlag(2)  
rangeBinNum(3)  
rainAve(3)  
weightW(2)  
method(2)  
epsilon(2)  
zeta(3)  
zeta_mn(3)  
zeta_sd(3)  
xi(3)  
thickThPIZ(2)  
nubfCorrectFactor(3)  
qualityFlag(2)
```

```
nearSurfRain(2)
nearSurfZ(2)
pia2a25(2)
errorRain(2)
errorZ(2)
spare(3)
```

Rainfall rate in mm/hr, profile for first scan, first ray(anglebin)

bin num	value	bin num	value	bin num	value
(0)	0.00	(1)	0.00	(2)	0.00
(3)	0.00	(4)	0.00	(5)	0.00
(6)	0.00	(7)	0.00	(8)	0.00
(9)	0.00	(10)	0.00	(11)	0.00
(12)	0.00	(13)	0.00	(14)	0.00
(15)	0.00	(16)	0.00	(17)	0.00
(18)	0.00	(19)	0.00	(20)	0.00
(21)	0.00	(22)	0.00	(23)	0.00
(24)	0.00	(25)	0.00	(26)	0.00
(27)	0.00	(28)	0.00	(29)	0.00
(30)	0.00	(31)	0.00	(32)	0.00
(33)	0.00	(34)	0.00	(35)	0.00
(36)	0.00	(37)	0.00	(38)	0.00
(39)	0.00	(40)	0.20	(41)	0.50
(42)	0.40	(43)	0.40	(44)	0.40
(45)	1.00	(46)	2.40	(47)	4.60
(48)	5.10	(49)	5.10	(50)	4.40
(51)	5.30	(52)	10.70	(53)	9.70
(54)	12.20	(55)	11.70	(56)	13.40
(57)	8.70	(58)	6.90	(59)	5.10
(60)	4.30	(61)	5.10	(62)	3.70
(63)	2.90	(64)	2.30	(65)	2.00
(66)	1.60	(67)	1.20	(68)	1.00
(69)	0.80	(70)	0.60	(71)	1.00
(72)	0.90	(73)	-88.90	(74)	-88.90
(75)	-88.90	(76)	-88.90	(77)	-88.90
(78)	-88.90	(79)	-88.90		

Geolocation for first 10 rays of first scan

Lat.	Lon.
31.464056	-88.948326
31.423845	-88.932983
31.383791	-88.917656
31.343937	-88.902374
31.304688	-88.887276
31.265430	-88.872147
31.226549	-88.857132
31.187859	-88.842155
31.149593	-88.827301
31.111242	-88.812393

```
****VDATA ELEMENTS***  
  
vdata_name: CLUTTER_FLAG  
fields: mainlobeEdge,sidelobeRange  
n_records: 49  
vdata_size: 4  
  
vdata_name: scan_time  
fields: scanTime  
n_records: 320  
vdata_size: 8  
  
vdata_name: pr_scan_status  
fields:  
missing,validity,qac,geoQuality,dataQuality,scOrient,acsMode,yawUpdateS,prMode  
,prStatus1,prStatus2,fractOrbitN  
n_records: 320  
vdata_size: 15  
  
vdata_name: pr_navigation  
fields:  
scPosX,scPosY,scPosZ,scVelX,scVelY,scVelZ,scLat,scLon,scAlt,scAttRoll,scAttPit  
ch,scAttYaw,att1,att2,att3,att4,att5,att6,att7,att8,att9,greenHourAng  
n_records: 320  
vdata_size: 88  
  
vdata_name: SwathStructure  
fields: VALUES  
n_records: 1  
vdata_size: 481  
  
Fractional Orbit Number, first 10 scans  
Scan Number      Fractional Orbit Number  
-----  
0          0.422187  
1          0.422296  
2          0.422406  
3          0.422515  
4          0.422625  
5          0.422734  
6          0.422843  
7          0.422953  
8          0.423062  
9          0.423172  
  
the end :-)
```

3.4 DIRECT HDF READ FROM FORTRAN

The FORTRAN HDF interface is similar to the C HDF interface. See the NCSA documentation on the WWW at <http://hdf.ncsa.uiuc.edu/doc.html>.

3.5 DIRECT HDF READ FROM IDL

The IDL program below lists the SDSs and Vdatas within the 2A-25 data product. Use the SDS and Vdata names from the list to read SDSs and Vdatas. Then the program reads one SDS, the rain rate SDS. The rain rate array is then unscaled and the missing data flag is treated separately. Then the program prints one ray of data from the rain SDS. Finally the program reads one Vdata, Scan Status, and prints one of the Scan Status fields, Fractional Orbit Number.

An alternative means to read a field from a TRMM HDF product into IDL will be provided by the TSDIS Orbit Viewer. Software and documentation may be found on the WWW at <http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html>. This capability will exist in the interactive mode and is scheduled for release in November 1998.

3.5.1 Program Source Code

```
; IDL_read.pro
;
; DISCLAIMER: This software is provided for users of TRMM data.
; TSDIS DOES NOT PROVIDE SUPPORT FOR THIS SOFTWARE.
;
; Sample code for reading some TRMM 2A-25 fields into interactive IDL
; Minimal error checking, be sure you are really reading a TRMM
; 2A-25 HDF file.
;
; Some of this source is hard-coded for 2A-25 for the sake of simplicity.
; The following fields are read from the file and are accessible from the
; IDL prompt after execution:
;
; SDSs:
; geolocation(nray,nscan)
; rain(ncell,nray,nscan) [nbin=80,nray=49,nscan= ~9150] This array is BIG.
; This sample only reads in all bins for all rays
; in first 10 scans.
;
; Vdata:
; PR_scan_status(nscan) -> Fractional Orbit Number
;
;
; All the above fields are documented in the TSDIS file specifications.
; READ THE FILE SPECIFICATIONS! They are described in the ICS Vols 3,4,6
; on the WWW at http://tsdis.gsfc.nasa.gov/tsdis/tsdis.html
;
; Also see the TSDIS Toolkit include files for the variable names
;
; No warranty expressed or implied. Some code copied from an RSI
; IDL/HDF example
;
; The Vdata code has been taken and modified from the TSDIS OrbitViewer
;
```

```
; Requirements: X-windows and lots of memory
;   Uses an X dialog box for filename input. If your not using X alter
;   the code and pass the filename as an argument.
;   This code also displays a sample plot of geolocation data. Comment
;   that out in the main routine if your not using X.
;
; Usage:
;
; IDL> .run IDL_read_HDF
;
;
;-----
;
;-----
;
; Procedure to read the SDS and Vdata fields

pro  read2a25, geolocation, rain, frac_orbit_num, file_only

      print, '----- Select a 2A-25 granule -----'
; Use built-in IDL to pop up a filename dialog box
      filen = dialog_pickfile()

;
; Do some error checking on the filename
; First 4 chars should be '2A-25'
; Call remove_path routine which is included below
      remove_path, filen,file_only
      first_four = ''
      reads, file_only,first_four, format='(A4)'
      if (first_four ne '2A-25')then begin
          print, 'Are you sure ',file_only,' is a 2A-25 HDF product?'
          print, 'If so, first 4 chars should be 2A-25'
          retall
          stop
      endif

      print, 'This may take some time if reading a full 250MB granule'
      print,''

; Initialize the scientific data set interface (hdf_sd* routines)
      sdsfileid = hdf_sd_start(filen,/read)

;
; Get info on the SDSs, number of SDSs and number of global attributes
      hdf_sd_fileinfo,sdsfileid,numsds,ngatt
      names = strarr(numsds)
      ndims = lonarr(numsds)
      dtype = strarr(numsds)

;
; Print out a table of the name, number of dimensions and type of each SDS
; in file
      for i = 0, numsds - 1 do begin
          sds_id = hdf_sd_select(sdsfileid, i)
          hdf_sd_getinfo, sds_id, name = na, ndim = nd,type= typ
```

```
names( i ) = na
ndims( i ) = nd
dtype(i) = typ
endfor
F1='( " ",A,I4)'
print,'List of SDS names'
print,'# of SDSs = ',numsdss,FORMAT=F1
print,''
if numsdss gt 0 then begin
    print,"      Label      Dims      Type"
    print,"----- ----- -----"
    for i=0,numsdss-1 do begin
        print, names(i),ndims(i),dtype(i),FORMAT='(A14,"      ,I4," ",A8," ")'
    endfor
    print,"----- ----- -----"
endif

; Read the geolocation SDS. This is kind of cheating since I know ahead of
; time that the name of the SDS is 'geolocation'. However, I could run
; the code above to find out the name of the SDS containing geolocation.

; Get ID of SDS
; This line calls another built in HDF function inside hdf_sd_select to
; translate the name of the SDS into an index.
sds_id = hdf_sd_select(sdsfileid,hdf_sd_nametoindex(sdsfileid,
'geolocation'))

; Read the SDS data into a variable. This reads the entire geolocation array
hdf_sd_getdata, sds_id, geolocation

; Read 3D rainfall array
sds_id = hdf_sd_select(sdsfileid,hdf_sd_nametoindex(sdsfileid, 'rain'))
hdf_sd_getdata, sds_id, rain,count=[80,49,10]
; If count is omitted above, the entire SDS will be read in. This line
; reads in all 80 vertical bins for all rays in the first 10 scans.
; For some reason using the count keyword also makes a temporary hidden
; variable that generates a message when returning from the procedure.
; Take the count keyword off and you won't get the message. No harm done.

; We are done with SDSs so we can close the interface
hdf_sd_end, sdsfileid

; Read in the Scan Status Vdata
; Scan status contains various flags for each scan. The fields are:
;
; Name          Size Type Position
; -----
; Missing        1byte int   0
; Validity      1byte int   1
; QAC           1byte int   2
; Geolocation Quality 1byte int   3
; Data Quality   1byte int   4
; Current SC Orientation 1byte int   5
; Current ACS mode    1byte int   6
; Yaw Update Status  1byte int   7
```

```
; PR mode          1byte int    8
; PR Status 1      1byte int    9
; PR Status 2      1byte int   10
; Fractional Orbit Num. 4byte float 11
;
; How did I know this?  READ THE FILE SPECIFICATIONS
;

; Open the file for read and initialize the Vdata interface
file_handle = hdf_open(filen,/read)

; Get the ID of the first Vdata in the file
vdata_ID = hdf_vd_getid( file_handle, -1 )
is_NOT_fakeDim = 1
num_vdata = 0

; Loop over Vdata
while (vdata_ID ne -1) and (is_NOT_fakeDim) do begin

; Attach to the vdata
vdata_H = hdf_vd_attach(file_handle,vdata_ID)

; Get vdata name
hdf_vd_get, vdata_H, name=name,size= size, nfields = nfields

; Detach vdata
hdf_vd_detach, vdata_H

; Check to see if this is a dummy
; Can't really explain why this happens but sometimes a dummy dimension
; gets returned as a Vdata name depending on the HDF file.
is_NOT_fakeDim = strpos(name,'fakeDim') eq -1

; Build up the list of Vdata names,sizes and number of fields
if (num_vdata eq 0) then begin
    Vdata_name = name
    Vdata_size = size
    Vdata_nfields = nfields
    num_vdata = 1
endif else if is_NOT_fakeDim then begin
    Vdata_name = [Vdata_name,name]
    Vdata_size = [Vdata_size,size]
    Vdata_nfields = [Vdata_nfields,nfields]
    num_vdata = num_vdata + 1
endif

; Get ID of next Vdata
vdata_ID = hdf_vd_getid( file_handle, vdata_ID )

endwhile

; Print out the list of names
print, ''
print, 'List of Vdata names      Size (bytes)      Num. Fields'
print, '-----'
```

```
for i = 0,num_vdata-1 do begin
    print, Vdata_name(i),Vdata_size(i),Vdata_nfields(i),$ 
        format='(A18,I10,I14)'
endfor
print, '-----'

; Find the Scan status Vdata
vdata_ID = hdf_vd_find(file_handle,'pr_scan_status')

; Attach to this Vdata
vdata_H = hdf_vd_attach(file_handle,vdata_ID)

; Get the Vdata stats
hdf_vd_get,vdata_H,name=name,fields=raw_field

; Separate the fields
fields = str_sep(raw_field,',',')

; Read the Vdata, returns the number of records
; The data for all records is returned in a BYTE ARRAY of (record_size,nscans)
; IDL will issue a warning to remind you there are mixed data types in
; the array
nscan = hdf_vd_read(vdata_h,data)
; Could have just read in the fractional orbit number with the
; fields keyword but this shows you how to extract the data from the
; full record BYTE array.

; Make up an array for the fractional orbit number
frac_orbit_num = fltarr(nscan)

; Loop over the records and pull out the fractional orbit number
for i = 0,nscan-1 do begin

; We know that the frac_orbit_number starts at position 11 in the byte array
frac_orbit_num(i) = float(data(*,i),11)
endfor

; Detach from the Vdata
hdf_vd_detach, vdata_H

; Close the hdf file
hdf_close,file_handle
return
end
;-----

;-----
; Procedure to remove path from file name
; Taken from OrbitViewer

    pro remove_path, file, file_no_path
;-----
;
```

```
;-----  
      file_no_path      = file  
  
      while( strpos( file_no_path , '/' ) ne -1 ) do $  
          file_no_path = strmid( file_no_path , $  
              strpos( file_no_path , '/' ) + 1, 1000 )  
  
      end  
  
;-----  
; Main routine  
;  
; All this does is call the read2a25 procedure and print out some values  
; The main routine returns you to $MAIN$ with the three  
; variables defined. Use 'help' to see them.  
;  
  
      read2A-25, geolocation,rain,frac_orbit_num,filen  
  
      print,'All data has been read, you can ignore the above warning'  
      print,''  
      print,'Hit Enter to output data to screen'  
      dummyy = get_kbrd(1)  
  
; UNPACK THE RAIN VARIABLE  
; The numbers in the file are mm/hr*10  
; The missing flag is not unscaled  
      rain_out=fltarr(80,49,10)  
      for i=0,79 do begin  
          for j=0,48 do begin  
              for k=0,9 do begin  
                  case rain(i,j,k) of  
                      -9999: rain_out(i,j,k) = -9999.0  
                      else:   rain_out(i,j,k) = rain(i,j,k)/10.0  
                  endcase  
              endfor  
          endfor  
      endfor  
  
; Print out some of the values  
      print,''  
      print, '----- OUTPUT for file ',filen  
      print,''  
; Rain rate profile for first ray in first scan  
      print, 'Rainfall rate in mm/hr, profile for first scan, first ray'  
      print, 'Index 79 is the Earth ellipsoid, bins have 250meter resolution'  
      print, 'Index Rainrate     Index Rainrate     Index Rainrate '  
      print, '-----'  
      for i = 0,79 do begin  
          print, i, rain_out(i,0,0),format='(I4,2X,F7.2,TR8,$)'  
          if (((i+1) mod 3) eq 0) and (i ne 0 ) then print,format='(/,$)'  
      endfor  
      print,''  
      print,''
```

```
; Fractional orbit number for first 10 scans
print, 'Fractional Orbit Number, first 10 scans'
print, 'Scan Number      Fractional Orbit Number'
print, '-----'
for i = 0,9 do begin
    print,i, frac_orbit_num(i),format='(I5,F25.8)'
endfor

; Plot the latitude for the nadir ray (24)
; Comment this out if you are not connected to an X device
plot, geolocation(0,24,*),/ynozero,title='Nadir Ray Latitude',$
    xtitle = 'Scan Number', ytitle = 'Latitude in degrees'
print, ''
print,'Type "help" to get a list of variables and sizes'

end
```

3.5.2 Run

This will only work if a full IDL license (rather than just a runtime license) was purchased. Since IDL has the capability to read HDF, separate HDF libraries are not needed. This software was tested on IDL version 5.0, but would likely work on earlier versions as well. From the UNIX prompt:

```
idl
IDL> .run IDL_read
```

The program uses a GUI to prompt the user for the input file. Then the user must hit RETURN when the program asks for it. A plot of the nadir latitude using x-windows will be displayed unless that section of IDL_read.pro is commented out.

3.5.3 Output

```
% Compiled module: READ2A-25.
% Compiled module: REMOVE_PATH.
% Compiled module: $MAIN$.
----- Select a 2A-25 granule -----
This may take some time if reading a full 250MB granule

List of SDS names
# of SDSS = 30

      Label      Dims      Type
-----  -----
geolocation      3      FLOAT
      rain      3       INT
      reliab      3      BYTE
correctZFactor      3       INT
attenparmNode      3       INT
```

attenParmAlpha	3	INT
attenParmBeta	2	INT
ZRParmNode	3	INT
ZRParmA	3	INT
ZRParmB	3	INT
zmax	2	FLOAT
rainFlag	2	INT
rangeBinNum	3	INT
rainAve	3	INT
weightW	2	INT
method	2	INT
epsilon	2	FLOAT
zeta	3	FLOAT
zeta_mn	3	FLOAT
zeta_sd	3	FLOAT
xi	3	FLOAT
thickThPIZ	2	INT
nubfCorrectFac	3	FLOAT
qualityFlag	2	INT
nearSurfRain	2	FLOAT
nearSurfZ	2	FLOAT
pia2a25	2	FLOAT
errorRain	2	FLOAT
errorZ	2	FLOAT
spare	3	FLOAT

List of Vdata names	Size (bytes)	Num. Fields
CLUTTER_FLAG	4	2
scan_time	8	1
pr_scan_status	15	12
pr_navigation	88	22
SwathStructure	481	1

```
% Compiled module: STR_SEP.
% HDF_VD_READ: Warning: Mixed data types. Converting to BYTES
% Temporary variables are still checked out - cleaning up...
All data has been read, you can ignore the above warning
```

Hit Enter to output data to screen

OUTPUT for file 2A-25_CSI.980812.4067.FLOR.3.HDF

Rainfall rate in mm/hr, profile for first scan, first ray
Index 79 is the Earth ellipsoid, bins have 250meter resolution
Index Rainrate Index Rainrate Index Rainrate

0	0.00	1	0.00	2	0.00
3	0.00	4	0.00	5	0.00
6	0.00	7	0.00	8	0.00
9	0.00	10	0.00	11	0.00
12	0.00	13	0.00	14	0.00
15	0.00	16	0.00	17	0.00
18	0.00	19	0.00	20	0.00

21	0.00	22	0.00	23	0.00
24	0.00	25	0.00	26	0.00
27	0.00	28	0.00	29	0.00
30	0.00	31	0.00	32	0.00
33	0.00	34	0.00	35	0.00
36	0.00	37	0.00	38	0.00
39	0.00	40	0.20	41	0.50
42	0.40	43	0.40	44	0.40
45	1.00	46	2.40	47	4.60
48	5.10	49	5.10	50	4.40
51	5.30	52	10.70	53	9.70
54	12.20	55	11.70	56	13.40
57	8.70	58	6.90	59	5.10
60	4.30	61	5.10	62	3.70
63	2.90	64	2.30	65	2.00
66	1.60	67	1.20	68	1.00
69	0.80	70	0.60	71	1.00
72	0.90	73	-88.90	74	-88.90
75	-88.90	76	-88.90	77	-88.90
78	-88.90	79	-88.90		

Fractional Orbit Number, first 10 scans
Scan Number Fractional Orbit Number

0	0.42218685
1	0.42229632
2	0.42240578
3	0.42251509
4	0.42262456
5	0.42273390
6	0.42284337
7	0.42295283
8	0.42306215
9	0.42317161

Type "help" to get a list of variables and sizes

4. ACRONYMS

C

CFAD Contoured Frequency by Altitude Diagram

E

EORC Earth Observation Research Center

F

FOV Field of View

G

GSFC Goddard Space Flight Center

GV Ground Validation

H

HDF Hierarchical Data Format

I

ICS Interface Control Specification

IDL Interactive Data Language

IFOV Instantaneous Field of View

IO Input/Output

IR Infrared

N

NASA National Aeronautics and Space Administration

NASDA National Space Development Agency (Japan)

NCSA National Center for Supercomputing Applications

NUBF Non-Uniform Beam Filling

P

PIA Path-Integrated Attenuation

PR Precipitation Radar

Q

QC Quality Control

S

SDS Scientific Data Set

SSM/I Special Sensor Microwave/Imager

T

TMI TRMM Microwave Imager
TRMM Tropical Rainfall Measuring Mission
TSDIS TRMM Science Data and Information System
TSU TSDIS Science User

V

VIRS Visible and Infrared Scanner

W

WWW World Wide Web